EVALUATION OF LEGUME COOKING CHARACTERISTICS USING A RAPID SCREENING METHOD

A Thesis

by

HWAY-SEEN YEUNG

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2007

Major Subject: Food Science and Technology

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Approved by:

Chair of Committee,	Lloyd W. Rooney
Committee Members,	Rhonda Miller
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ABSTRACT

Evaluation of Legume Cooking Characteristics Using a Rapid Screening Method. (December 2007)

Hway-Seen Yeung, B.S., University of Houston

Chair of Advisory Committee: Dr. Lloyd W. Rooney

Consumer preferences for legume cooking properties should be considered at an earlier stage in the breeding process. Hence, we developed an effective, low-cost method to analyze the cooking quality attributes of cowpeas. The objective was to develop a rapid screening method to evaluate the cooking quality attributes of cowpeas (*Vigna unguiculata*) and compare the results with currently used methods. Soaked samples (five grams) were boiled for 27 min, and seeds and their broth were separated into dishes with covers. Samples were subjectively rated on a 1-5 scale for cooked doneness, tactile texture, aroma intensity, and opacity of the broth. Water absorption, seed splitting, and soluble solid loss were also determined. The samples were evaluated in batches of 25 and replicated three times.

Cooking properties showed significant correlations with each other, but did not correlate with raw seed size and color. The method is important because consumer acceptability largely depends on cooking quality in addition to seed appearance. Many properties like cooked doneness and tactile texture were significantly affected by genetics and environment.

Compression force determined with a Texture Analyzer (TA) significantly correlated with doneness and tactile texture ratings at -0.67 and -0.69, respectively ($P < 0.01$). Cooking times from the Mattson bean cooker (MBC) were significantly correlated with doneness and tactile texture at -0.63 and -0.65, respectively ($P < 0.05$). The Texture Analyzer and MBC confirmed the subjective ratings of cooked doneness and tactile texture. A procedure to determine solid losses using a refractometer, instead of the time-consuming oven-drying method, saved time and has significant promise for use in simple evaluations.

The rapid cooking method required 2 hr on the first day and 5 hr on the second day to evaluate 25 samples. The method is efficient, repeatable and uses inexpensive materials compared to the TA and MBC. It also provides descriptive information, and differentiates legume cultivars based on cooking properties. This method is a useful tool in the breeding program for selecting and advancing promising lines. Food processors may also use this method for a quick evaluation to check if their legumes meet required specifications for processing.

DEDICATION

In Loving Memory of Dr. Ralph Waniska

ACKNOWLEDGEMENTS

Many have played an important role in the completion of this thesis, and I am grateful for the opportunity to express my gratitude towards all of them.

First, I would like to sincerely thank Dr. Lloyd Rooney for his encouragement and invaluable assistance. I learned from him that it is better to make mistakes and build “scar tissue” than not to try at all. I would also like to thank Dr. Luis Cisneros and Dr. Rhonda Miller whose guidance and assistance has greatly benefited me in my studies at Texas A&M. I appreciate their time, knowledge, and willingness to serve on my committee.

I would like to extend a heartfelt and sincere thanks to the late Dr. Ralph Waniska. Words cannot express how much I appreciate everything he has done for me. His commitment, honesty, and wealth of knowledge have shaped the development of my character in many ways. It was an honor to work with him, and he is dearly missed.

I would also like to express my appreciation to everyone in the Cereal Quality Lab for their support and most importantly, their friendship. Special thanks to Cassandra McDonough, who has offered great advice and a listening ear; and to Novie Alviola for being a tremendous help and generously sharing her wisdom. Thank you to Pamela Littlejohn who is an asset to the CQL for her day to day assistance.

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Thank you to Jeff Ehlers for generously providing the cowpea samples, as well as his assistance in my research.

Thank you to my family and friends; their prayers and moral support have carried me through this journey.

And last but not least, I thank Jesus Christ to whom I give all the glory. It is by his grace that I have learned to be content in any and every situation.

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CHAPTER I

INTRODUCTION

Cowpea is a drought-resistant crop with the nodule bacteria *Bradyrhizobium* spp. Cowpea is able to survive in hot, dry soil conditions with low fertility requirements. The grain contains about 23-25% protein, 6.3% fiber, and 50-67% starch (Singh 1997), providing a nutritious food for urban communities of Africa, Latin America, and Asia. The crop's favorable characteristics play a key role in the subsistence of millions of people in developing countries.

Since cowpeas are typically consumed as cooked seeds, it is important to produce varieties with qualities that meet desired consumer preferences. Cooking time is an essential characteristic commonly used to determine quality of cooked seeds. Extended cooking times required for some cowpea cultivars are undesirable and require excessive energy. Methods used to evaluate legume quality require excessive time or large quantities of grain. There are currently no methods that allow evaluation of various cooking characteristics of several varieties in one trial.

Equipment currently used to measure cooking time of cowpeas is difficult to use and requires excessive time and expense. The Mattson bean cooker measures cooking time using weighted plungers. The method requires

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This thesis follows the style of Cereal Chemistry.

continuous attention and is difficult for the operator to record if several seeds reach the cooked state at the same time. A Texture Analyzer is used to measure kernel hardness and optimal processing temperature and time. Time and costs could be substantially reduced in processing if Texture Analyzer and Mattson bean cooker results can be predicted by subjective evaluations conducted by a trained evaluator.

Legume quality is also affected by the presence of distinct flavor and superior organoleptic qualities. Sensory panelists give high ratings to cooked seeds with good appearance, taste, and mouthfeel (Negri et al 2001). Breeding programs have focused on visible characteristics of raw seeds to determine seed quality; however, visible characteristics are not always reliable indicators of cooking characteristics, which are of great importance to consumers.

As improved cowpea varieties are developed to overcome challenges of new diseases and achieve goals for higher yield, consumer preferences for cowpea products must be considered at an earlier stage in the breeding process. Thus an effective, low-cost method to analyze the attributes of advanced lines and new varieties, to differentiate legumes into consumer-preferred and -less preferred categories.

Objectives

1. Develop a quick, repeatable, and inexpensive screening method that can be used to evaluate cooking properties of legumes in a breeding program

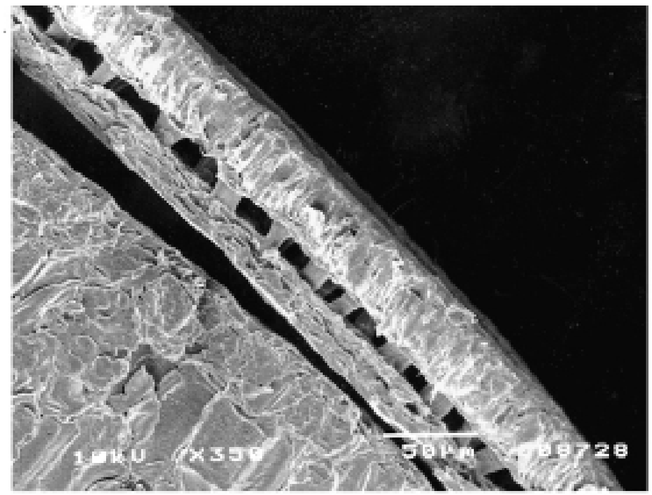
2. Verify accuracy of the quick screening method developed by comparing with the following methods:
    - Mattson bean cooker- to verify doneness
    - Texture Analyzer- to verify texture and doneness
    - Dry oven method- to verify total solid loss

CHAPTER II

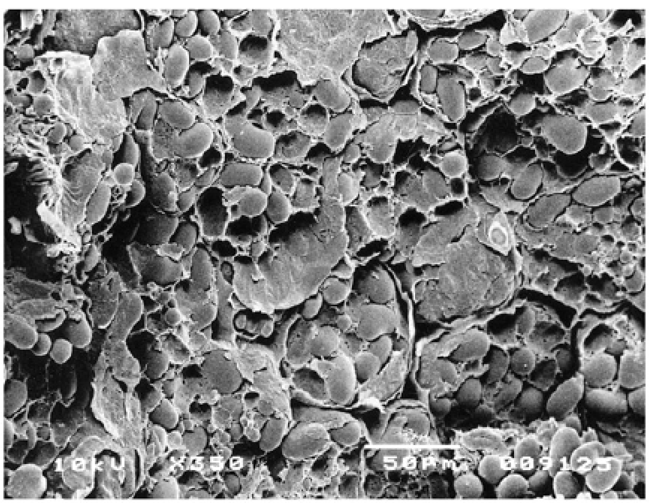
LITERATURE REVIEW

Structure of cowpea seeds

Cowpeas are dicotyledon seeds measuring from 5-30 g per 100 seeds and 2-12 mm in length (Taiwo 1998). The color of seeds will vary depending on the genetic makeup and amount of phenolic compounds present. Flavenoid pigments are responsible for the wide range of seed coat colors in cowpeas (Beninger et al 1998). Cowpea seed coats may be rough, wrinkled, or smooth in texture, with rough coats more firmly attached to the cotyledon than smooth coats (Olapade et al 2002). The outer area of the seed coat consists of palisade cells that form a layer along the radial axes of the seed and hour glass cells found beneath the palisade cells (Lush and Evans 1980) (Figure 1, A.). During water absorption, the seed coat is the structure that initially affects the rate of water absorption, with thinner coats allowing a higher initial rate of absorption than thicker coats (Sefa-Dedeh and Stanley 1979). In addition, the size of the hilum and micropyle plays a role in water imbibation (Sefa-Dedeh and Stanley 1979). The color of the hilum is often part of the name depending on the region; for example, the black-eyed pea and purple-eyed pea are common names for peas consumed in the U.S., while cream peas mean the hilum is colorless. The cotyledon cells are the major storage organs in the seed, with carbohydrates and protein being the major consituents (Blaszczak et al 2007). It consists of parenchyma cells, which are comprised of starch granules and protein bodies in a cytoplasmic matrix (Figure 1, B.). Individual parenchyma cells are cemented together by the middle lamella (Sefa-Dedeh et al 1978).



A.



B.

Fig. 1. Microstructure of a raw cowpea (Blaszczak et al 2007).

- **A.** Seed coat composed of palisade layer, followed by hour-glass cells, and a spongy parenchyma.
- **B.** Cotyledon composed of starch granules covered with protein material. The middle lamella separating each parenchyma cell is clearly visible.

Cooking of cowpeas

When cooked at 100°C, the middle lamella begins to break down, resulting in the separation of parenchyma cells and softening of the seed texture (Sefa-Dedeh et al 1978). Gelatinization of the starch occurs when heated granules absorb water and swell, losing their semicrystalline structure. Swelling causes amylose to leach out of the cell and associate (Thomas and Atwell 1999). The gelatinization process is one of the major physicochemical changes that contribute to the softening of cowpea seeds. There is a complete loss of cellular structure in cooked seeds, where cell wall materials and starch granules are not visible (Bhatty et al 1983).

Cooking methods

Existing cooking methods for legumes do not evaluate sufficient samples in one trial. Methods typically include materials and procedures that allow for evaluation of only a few samples and their characteristics at a time. Cooking more than one sample typically involves boiling in separate cooking containers (Proctor and Watts 1987, Negri et al 2001). This involves the time-consuming task of staggering the start of the cooking time in order for all samples to cook for the same amount of time. When cooking is completed, samples are drained and sometimes cooled to room temperature for up to two hours in covered plastic containers prior to analysis (Scanlon et al 1998). A methodology that can rapidly screen several samples for their cooking attributes is needed.

Cooking time

A reduction in cooking time is advantageous because it requires less energy and fuel. Nutritional value is also improved by lower losses of leached nutrients as well as the destruction of heat labile vitamins during prolonged cooking (Akinyele et al 1986). Various methods have been used to measure legume cooking time, but no universal method has been established (Wang et al 2003). Reported methods involve the Mattson bean cooker and texture instruments, which provide objective data but can be costly and/or time consuming. Other methods include sensory analysis, which has been deemed the best method to calibrate texture instruments (Bourne 1982). Consumers are willing to pay between 0.7% and 1.2% above the original price for a one minute reduction in cooking time (Faye et al 2004); therefore, a method that efficiently determines cooking time of legumes is highly beneficial.

Mattson bean cooker

The Mattson bean cooker (MBC) measures cooking time by evaluating the time required for each of 25 beans to reach a level of softness. Time is recorded as each weighted plunger punctures a bean while cooking in boiling water. Proctor and Watts (1987) showed that cooking time of navy beans determined by sensory evaluation was reproduced using a MBC at CT_{92} (92% cooked point). Wang et al (2003) compared the MBC with the tactile method for determining cooking time. At CT_{80}, the MBC and the tactile method produced the same results. The MBC has been used as a reference to verify rapid screening tests for cooking time.

Texture Analyzer

Texture of cooked seeds has been obtained by measuring the force required to compress a sample. Scanlon et al (1998) used the Ottawa Texture Measuring System wire extrusion cell on lentils. At 40% compression, a positive correlation was found between peak force and sensory measurements of hardness, chewiness, and particle size. The 40% compression simulated the initial bite of the first molar (Bourne 1982). Dolan et al (2003) reported that measurements using a Kramer shear press on sugar-cooked beans could be predicted by a sensory panel. Time and costs may be reduced by using a sensory method that involves chewing samples and using mouthfeel.

Mouthfeel

A method of using mouthfeel to determine cooking time is to periodically remove seeds from their cooking container for panelists to taste (Aremu 1991, Liu et al 2005). When seeds reach their desired tenderness, cooking time is recorded. Other methods include cooking seeds in separate containers at various times and using mouthfeel to select the optimal time (Taiwo et al 1997). In a study by Scanlon et al (1998), lentils were grouped by panelists into three categories: under-, over-, and optimally cooked. Grouping was based on how easily the lentils gave way to pressure put forth between the molars during the first bite and subsequent particle breakdown during mastication.

Soak water absorption

Soaking legumes before cooking inactivates or reduces antinutrient constituents and increases product yield. Soaking also assists tenderness by ensuring uniform expansion of the seed coat and cotyledon and allowing for better heat transfer during cooking (Hoff and Nelson 1965). Taiwo et al (1997) reported cooked cowpea samples that had been presoaked were softer in texture than unsoaked samples. Wang et al (1979) also reported that tenderness of cooked soybeans was increased by soaking prior to cooking. In addition, the study showed that unsoaked beans were cooked twice as long to reach similar tenderness to soaked beans.

The amount of water absorption has been commonly used to determine legume quality. It is a general theory that the amount of water absorbed before cooking is negatively correlated with cooking time (Sefa-Dedeh et al 1978, Liu et al 2005). Variations in water absorption, however, have contrasted with the theory. Wang et al (1979) found that partially soaked (100% absorption) soybean seeds produced the same amount of cooked tenderness as seeds that were fully hydrated (142% absorption). Sefa-Dedeh and Stanley (1979) explained that during the initial stage of soaking, seed coat thickness and hilum size influenced water absorption, while protein content was the major factor in the later stages of soaking. Factors that contribute to the variations are thickness and texture of the seed coat, how firmly the seed coat is attached to the cotyledon, size of the hilum and micropyle, and size of the overall seed (Akinyele et al 1986, Sefa-Dedeh and Stanley 1979, Demooy and Demooy 1990, Olapade et al 2002, Wang et al 2003). Barriers during soaking are sometimes eliminated during cooking; thus, water absorption is inconsistent among legumes and is not a reliable method of determining cooking time.

Effect of soak water absorption on solid loss

Humans lack the enzyme alpha-galactosidase needed to digest alpha-galactosides present in legumes. The oligosaccharides are fermented in the large intestine and produce gases that cause flatulence and/or diarrhea. This is a major deterrent for consumption of legumes among consumers, and also for children in developing countries where cowpea is a source of food.

Soaking raw cowpeas in distilled water reduces the level of oligosaccharides (Somiari and Balogh 1993). Akinyele and Akinlosotu (1991) reported that cowpeas soaked for 4 hr resulted in a 32.2% decrease in total oligosaccharides, which improved digestion. A portion of the solids lost included verbascose, raffinose and stachyose. Soaking time positively correlates with the amount of solids lost. Legumes that are cooked without presoaking have significantly higher oligosaccharide content; and therefore cause a higher rate of indigestion (Han and Baik 2006).

Methods used to measure soak water absorption

Samples are generally soaked in separate containers of distilled water (Taiwo et al 1997, Liu et al 2005). Soaking occurs at room temperature for 12-16 h to ensure equilibrium (Sefa-Dedeh et al 1978, Proctor and Watts 1987, Scanlon et al 1998). Water is drained, at times using a sieve, and seeds are blotted to remove surface water. The weight gain in seeds is taken as the amount of water absorbed (Sefa-Dedeh et al 1978, Mwangwela et al 2007).

Legume quality characteristics

Sensory characteristics of legumes are of importance to breeders as they influence consumer preferences. Previous analysis of consumer demand focused on visible characteristics of raw seeds. Colored seeds are sometimes favored, while others are attracted to white seeds because they do not tint the color of the cooking water that is often served with the beans (Negri et al 2001). Smooth seed coat texture is desirable for whole seed consumption, whereas wrinkled coats are easier to dehull for flour production. Faye et al (2004) reported that some consumers are willing to pay a higher price for legumes that are larger in size.

Visible characteristics of raw seeds, however, are not a reliable measure for cooking quality. Legumes with similar appearance may have significantly different cooking properties. In a study by Akinyele et al (1986), cowpea cultivars with varying seed coat colors were analyzed for cooking time, swelling capacity, solids loss, and soluble sugars. Correlations were not found between seed color and the measured properties, showing that color preference does not have a scientific basis. Seed coat texture of the cultivars was also compared to cooking time and no correlation was found.

In addition to visible characteristics, legumes with good overall flavor are given higher ratings by sensory panelists. Components of flavor typically involve taste, mouth-feel, and aroma (Taylor and Roberts 2004). Chewing allows for the transport of aroma compounds from the food to the gas phase in the mouth and then to the nose (Dunphy et al 2006). Although the intensity of an aroma cannot give a false impression of flavor when flavor is absent (Stevenson et al 1999), aroma intensity can enhance or suppress taste intensity (Prescott 1999). Consumers are usually unaware that their sense of smell affects flavor perception. Legumes should be evaluated for overall flavor, a quality identified after cooking.

Splitting in the testa and cotyledon is another important quality attribute of legumes depending on the function. In canned beans, a low number of beans with splitting in the testa is preferred; however, excessive splitting or splitting in the cotyledon is not desirable (Van Buren et al 1986, Taiwo 1998). Cowpeas that were soaked were found to have reduced splitting compared to seeds that were not soaked (Taiwo et al 1997).

Seed size is a quality that has been associated with the cooking time of legumes. Olapade et al (2002) reported that conduction is anticipated to be the primary mode of heat transfer within cowpea seeds; therefore, smaller seeds receive heat faster in the interior during cooking. On the contrary, Demooy and Demooy (1990) reported that smaller cowpea seeds required the longest cooking time. There has not been strong evidence that cooking time is dependent on seed size.

In West African countries, farmers buy what is available when they reach the market; products that are low in supply are substituted with products of similar appearance (Faye et al 2004). Almost all those who are involved in the process of transporting cowpeas to the buyer have specified a need for information on buyers' preferences, which differ depending on the country. Breeders especially benefit from this knowledge when they are making selections in their improvement programs to develop good tasting acceptable cowpea varieties. More research is needed to include cooking qualities in the analysis of consumer demand.

CHAPTER III

DEVELOPMENT OF SCREENING METHOD FOR MEASURING COOKING QUALITY

Materials and methods

Raw cowpeas

Seventy cowpea samples were donated from the Department of Botany and Plant Sciences, University of California, Riverside (Figure 2). Cultivars were grown and harvested at two locations, Fall Coachella Valley and UC Riverside. Seeds were sealed in containers and placed in cold storage at a temperature of -10°C. Before cooking, measurements were made on seeds to test for the effects of these characteristics on cooking quality. Length was determined by measuring 10 randomly selected seeds, and weight was determined by weighing 80 randomly selected seeds. Color determination was carried out using the Minolta CT-310 colorimeter (Model CT-310, Konica Minolta Sensing Americas, Inc., Ramsey, NJ) to find whether lightness and darkness of raw seeds affect color of the cooked broth. Seeds that were undamaged and representative of the lot were hand selected for the screening method.

Fig. 2. Raw cowpea samples

Screening method

Soak absorption

Samples were soaked using a modified method of the Canadian Grain Commission (2005). Five gram samples were placed in labeled plastic bags containing three punched holes at the top (Figure 3). Plastic bags (17.7 cm x 12.7 cm, Ziploc Brand Freezer Bags) were selected based on their ability to withstand boiling temperature. Bags were filled with 60 g of deionized water (Figure 4), which avoided the effect of ions on cooking time (Scanlon et al 1998). To ensure uniform expansion, as well as maximum water imbibation, seeds were soaked at room temperature (20-25°C) overnight for 16 hr (Onayemi et al 1986). Then water was drained through a hole punched in the bag and kept in separate bowls. Originally, broth was drained using clothespins to hang bags upside down for 10 min. The method was changed to manually draining the broth and shaking bags gently to remove excess liquid. The increase in seed weight was calculated as the amount of water absorbed; the soak water was returned to its respective bag.

Fig. 3. Five gram cowpea sample in 3-hole punched plastic bag

Fig. 4. Cowpea sample soaked 16 h in 60 mL deionized water

Cooking

Twenty-five cowpea samples were selected for each trial. Subsequent to soaking, the 25 plastic bags with seeds were supported by two rods in a container of boiling water (Figure 5). The container was 11.5 inches in height and 16 inches in diameter. Rods were placed through holes punched in the bags. This enabled the bags to hang in a parallel position between the rods and remain stable. Using two rods to support the bags prevented the possibility of broth spilling during the process of soaking and cooking. The height of the water level in the container was 8.5 inches. Placing two marbles in each bag was also initially considered to prevent the bags from floating during cooking and ensuring that the seeds remained below water level; however, bags remained submerged

Fig. 5. Samples held by rods and boiled in cooking container

without the marbles. Samples were boiled in their soak water for the predetermined cooking time using an electric stove and at a distance of 5.5 inches above the heating element (Figure 6). The distance from the heating element affects the cooking time and is critical when comparing one cooking method with another. Samples were weighed after cooking, and the increased weight was used to determine the amount of water absorbed during cooking (cook absorption).

End effects were noted among the samples, where cooked seeds at each end of the row of 25 bags experienced a slightly less tactile texture and doneness rating. The cause of the end effects can be explained by the differences between the diameters of the heating element (7.5 inches) and the cooking container (16 inches) (Figure 6). Since the heating element only had direct contact with the bottom-center of the container, water in the center of the container may have risen to higher temperatures than the water in the outer edges. Thus, it was important to keep bags in the center of the cooking container by placing pseudo bags at each end of the row of 25 bags, which eliminated the end effects.

In every cooking trial, the order of samples was randomized. Cooking trials were performed in triplicate, with each trial conducted on a different day.

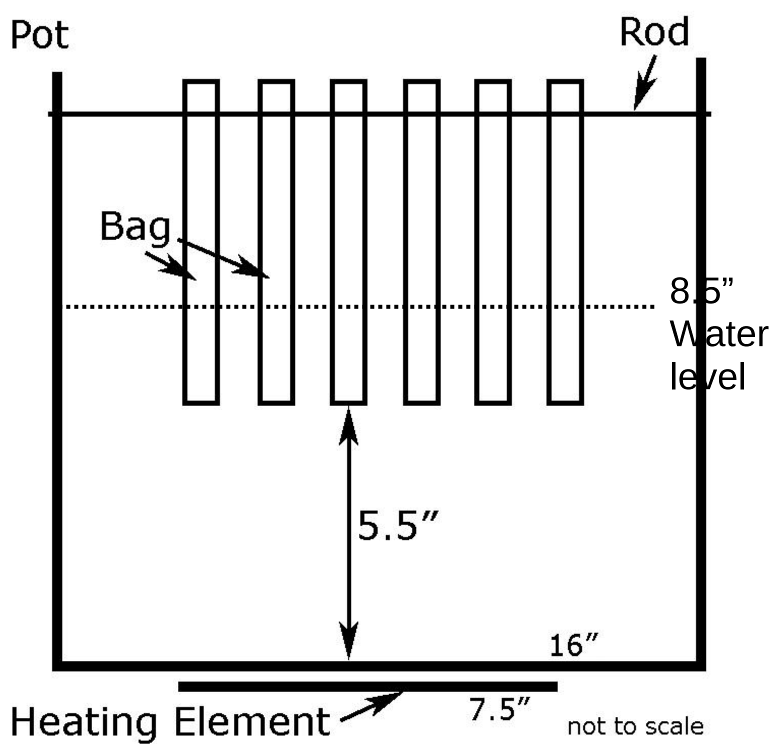


Fig. 6. Distance of the bags from the heating element (5.5 in) affects the rate of cooking. Size of the pot (16 in) compared to the heating element (7.5 in) caused end effects.

Establishing cooking time

Two cooking trials were performed before starting the experiment. All 70 samples were soaked overnight and cooked in separate bags for 25 min. Cook time of the initial trial was decided based on our previous experiences of cooking cowpeas and evaluation of reports in the literature. Cooking time commenced when samples were placed into a container of boiling water at 100°C. The boiling temperature of water depends on the atmospheric pressure and varies depending on location.

To determine whether samples were adequately cooked, four seeds were chewed using the molars and then compressed against the palate with the tongue to evaluate particle size. Samples were rated on a scale of 1-5 for doneness (1= undercooked, 5=overcooked). Tactile texture was the method used to determine cooked adequacy; however, certain samples with low resistance to pressure between the fingers still possessed grittiness when chewed in the mouth. Since grittiness is an indication that a sample is inadequately cooked, mouthfeel served as a better method to determine the adequacy of cooked seeds.

The 25 min cooking time gave 56% of the samples, ratings of one to two (undercooked), 34% of samples received a three (adequately cooked), and 10%, four to five (overcooked). To establish a time where the majority of samples were adequately cooked, a second cooking trial was conducted. Samples were cooked for an adjusted time of 27 min, resulting in 44% of samples rated one to two (under- and slightly undercooked), 44% rated three (adequately cooked), and 11% rated four to five (overcooked). The second trial was performed in duplicates on separate days. Aremu (1991) reported a range of 23-53 min for cowpea cooking time. Twenty-seven minutes was selected as the cooking time for the rapid screening method.

Trained evaluator

After cooking, the cooked seeds and broth were emptied into separate bowls with lids (Figure 7). One evaluator was trained by initially conducting cooking trials to find samples that possessed the preferred sensory characteristics and define ratings for the 1-5 scales. The following parameters were rated. Aroma of seed and broth was measured by taking one sniff and rated: 1=nearly none, 2=faint, 3=apparent, 4=more apparent, 5=pungent. Tactile texture was measured by pressing at least three seeds, one at a time, between the thumb and forefinger and rated: 1=seed is difficult or not able to smash and cotyledon feels hard, 2=seed is less difficult to smash and cotyledon feels slightly hard, 3=seed is firm but smashes easily and cotyledon feels soft, 4=there is little resistance to smash seed and cotyledon feels mushy, 5=seed is easily pressed into a mush. Cooked doneness was measured by the same method to establish cooking time and rated: 1=undercooked, 2=slightly undercooked, 3=cooked, 4=slightly overcooked, 5=overcooked. Broth opacity was measured by placing bowls on white paper with black text and rated: 1=text legible and clear, 2= text legible but blurry, 3= text very blurry and/or may not be legible, 4

=cannot see text, but able to see a silhouette of any object when the bowl is lifted off paper, 5=completely opaque (Figure 8). Seed coat and cotyledon splitting were evaluated by counting the number of torn seed coats and cracked cotyledons (Figures 9 and 10). To produce an accurate sensory evaluation, the evaluator must avoid smoking, chewing gum, or eating 1 hr prior to and during the evaluation. Finally, the evaluation area should be noise and odor free with adequate light.

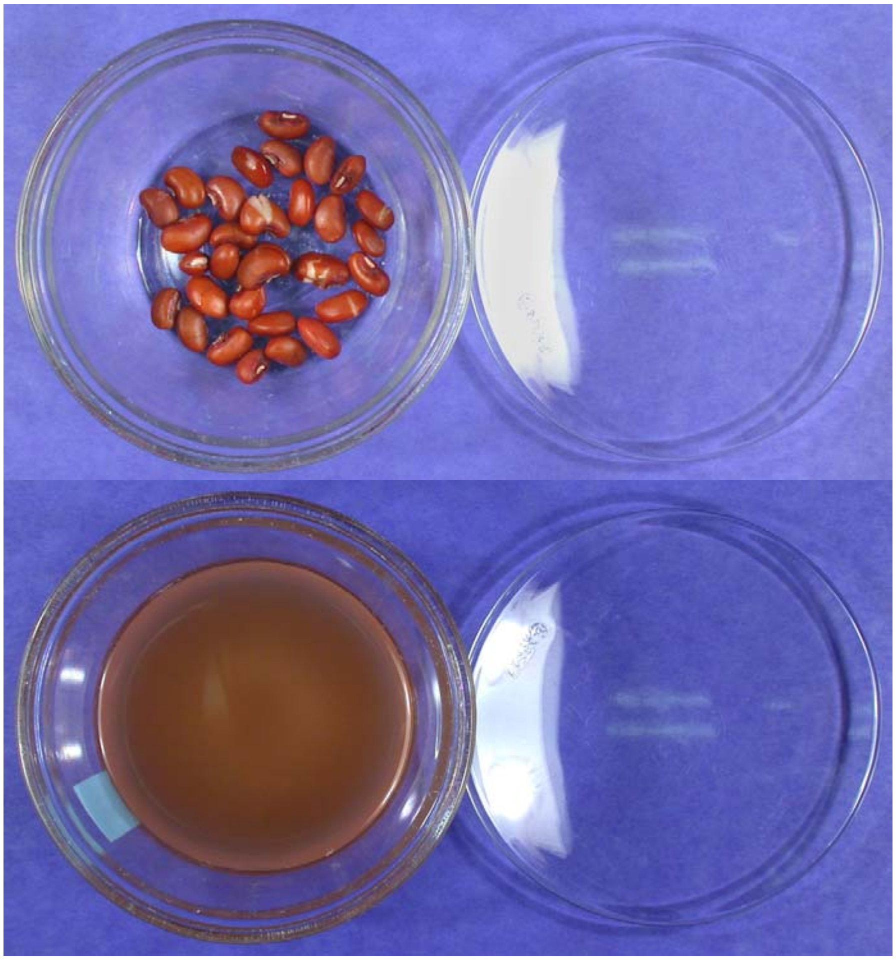


Fig. 7. Cooked seeds and broth in bowls with lids

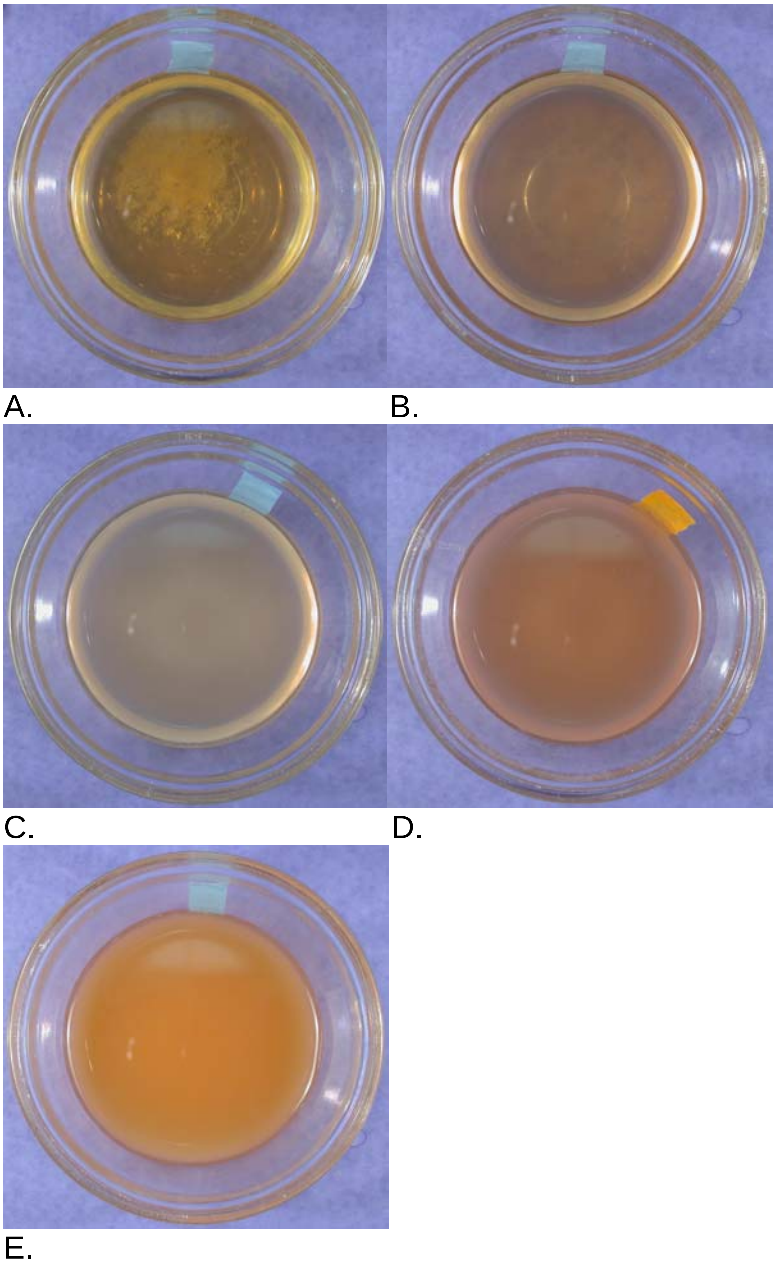


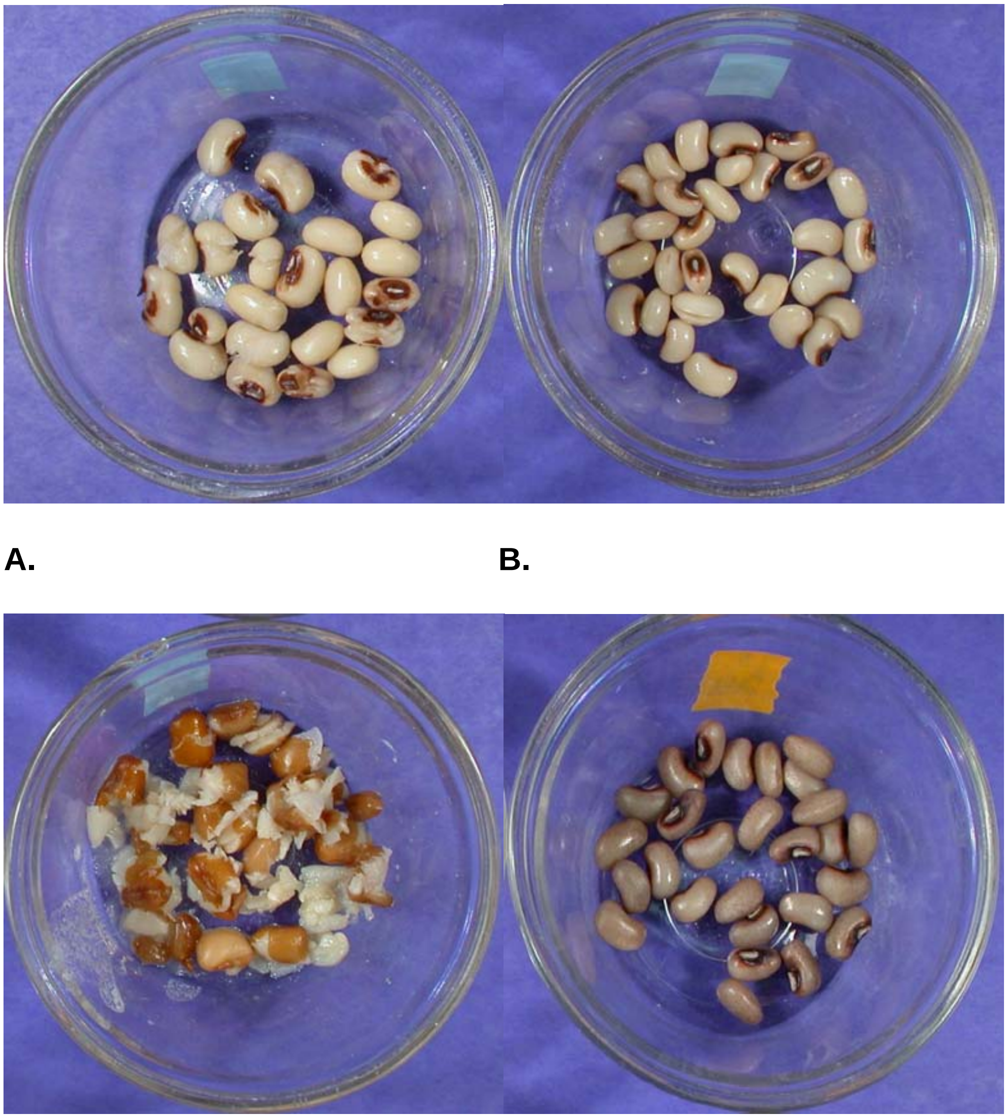
Fig. 8. Examples of broth opacity ratings for different varieties and their locations A. Rating 1, IT95K-181-9, 05FCV-25, B. Rating 2, CB46, 05-15-820 C. Rating 3, IAR7/8-5-4-1, 05FCV-42, D. Rating 4, Mounge, 05FCV-51, E. Rating 5, IT97K-556-6, 05-15-825

A.

B.

C.

Fig. 9. Cooked seed defects. **A.** Split testa, **B.** Separation of the cotyledons, **C.** Crack in the cotyledon



A. B.

C. D.

Fig. 10. Some samples exhibited significantly more splitting than others after cooking. **A.** Split testa 80%, Split cotyledon 83%, CB46, 05-15-820, **B.** Split testa 5%, Split cotyledon 5%, IAR7/8-5-4-1, 05FCV-42, C. Split testa 99%, Split cotyledon 96%, IT85F-3139, 05-15-833, D. Split testa 6%, Split cotyledon 6%, Mounge, 05FCV-51

Aroma is lost over time, and pungency decreases as temperature cools. Thus, aroma was evaluated immediately after cooking while samples and broth were still warm. Evaluation of splitting required intact and untouched seeds. It was evaluated before tactile texture and doneness. Broth opacity was evaluated last because time had less effect on this parameter. A specific characteristic was evaluated for all samples before moving on to the next characteristic. However, doneness and tactile texture characteristics were alternated during evaluation because it was more time-effective to evaluate them together.

Twenty-five samples per cooking trial were the maximum limit before the evaluator reached sensory fatigue. In the determination of cooking time, 70 samples were cooked at once because only one parameter was being tested, and fatigue was not a significant concern.

Measuring solid loss using a °Brix refractometer

The percentage of soluble solids lost after cooking was measured by determining °Brix using a refractometer (ATAGO Pocket PAL-1). Broth was first swirled to disperse solids settling at the bottom, and 0.6 mL was taken up using disposable polyethylene transfer pipets for measurement. After cooking, the final broth weight was estimated in grams using the following formula:

Final Broth WT = 60 g - (Final Seed WT – Initial Seed WT)

The following formula was used to calculate soluble solid losses:

$$\text{Soluble Solids} = \frac{(^\circ\text{Brix})\ (\text{Final Broth WT (g)})}{\text{Initial Seed WT (g)}} * 100$$

Statistics

Significance of difference between samples was determined by the least significant difference (LSD) in SPSS. Correlations between qualities were determined using Pearson's Correlation in SPSS.

Results and discussion

Screening method

Of the cowpea samples, cultivars grown in more than one location were averaged for their raw physical characteristics and cooking characteristic values (Table I). Weight and length of raw seeds ranged from 0.13-0.27 g per seed and 7-11 mm per seed respectively, similar to a report by Taiwo (1998). Colorimeter "L" values on raw samples ranged from 31.9-70.9. "a" values ranged from 0.35-14.1, and "b" values ranged from 0.82-22.9. Soak absorption ranged from 2.17-2.73 g of water per gram of sample. Cook absorption in our experiment ranged from 2.52-3.27 g of water per gram of sample. Splitting of the testa and cotyledon ranged from 2.5-99% and 2.6-98% respectively. Soluble solid losses ranged from 7.2-14%.

Table II shows the correlations between the characteristics measured. Raw characteristics did not correlate with sensory characteristics of cooked seeds. No correlations were found between seed size (weight and length) and sensory characteristics of doneness, tactile texture, aroma, splitting,

TABLE I
Characteristics of Cowpea Varieties Cooked for 27 Minutes and Physical Characteristics of Raw Cowpea Varieties

Variety	Cook Done[1]	Tactile Texture	Soak Abs (%)	Cook Abs (%)	Cook Broth Aroma	Cook Bean Aroma	Splt Testa (%)	Splt Cotyl (%)	Broth Opacity	Solid Loss (%)	Seed Wt(g)[2]	Seed Length (mm)[2]	L*[2]	a*[2]	b*[2]
IT84S2246	5.0	5.0	134	227	1.8	1.8	98	98	1.7	11	0.20	8.80	51.76	11.79	22.85
IT98K-128-2	4.5	4.5	126	202	3.0	2.7	82	82	1.7	8.9	0.21	9.50	65.20	2.50	17.98
IT85F-3139	4.1	4.0	133	190	2.8	1.8	99	97	1.2	9.8	0.22	8.60	46.78	11.38	19.76
Mouride	3.8	4.0	135	175	1.6	1.8	90	90	3.0	8.9	0.23	8.80	63.77	3.26	17.33
IT97K-569-9	3.7	3.8	126	219	2.3	2.3	84	84	2.3	9.3	0.18	8.70	64.95	3.17	17.04
IT98K-498-1	3.6	3.2	157	201	2.6	1.6	97	95	2.0	12	0.17	8.80	65.48	2.60	16.13
IT93K-693-2	3.3	3.3	132	183	2.0	1.8	80	75	1.5	9.0	0.20	9.20	47.45	12.17	19.93
CB27	3.2	3.2	133	181	3.0	2.2	55	52	3.3	9.1	0.22	9.85	63.61	2.77	13.92
1393-1-2-2 (+)	3.0	3.0	141	171	2.0	1.8	29	28	3.5	8.5	0.27	10.50	62.30	2.92	12.82
1393-2-3 (-)	3.0	3.0	138	183	1.5	1.8	31	31	3.0	9.0	0.24	10.30	61.45	2.95	12.88
IT86F-2014-1	3.0	3.3	158	215	3.0	1.7	89	84	4.3	12	0.13	8.20	46.84	11.54	17.70
IT93K-2046	3.0	2.7	143	173	2.3	3.3	42	33	2.3	8.7	0.21	10.80	66.25	2.10	19.32
IT95K-207-21	3.0	2.8	128	181	3.2	2.8	99	87	1.8	10	0.26	10.60	53.12	8.63	20.74
IT97K-499-39	3.0	3.0	132	161	2.4	2.2	30	27	2.2	9.4	0.20	9.00	67.18	1.49	18.78
IT98K-205-8	3.0	2.8	117	156	2.8	2.6	42	42	2.0	7.2	0.21	9.00	67.26	2.72	18.09
IT98K-428-4	3.0	3.0	140	169	2.2	1.8	20	19	2.5	8.7	0.18	9.00	68.85	2.74	15.77
Prima	3.0	3.0	152	179	2.8	3.2	29	27	4.0	9.8	0.16	8.65	63.57	3.24	15.70
CB46	2.8	3.2	129	186	3.3	2.7	75	76	2.5	8.4	0.23	9.45	62.06	2.79	14.58
IT89KD-288	2.8	2.7	132	161	1.6	2.1	32	23	3.0	8.7	0.25	9.80	68.14	2.63	15.77
KVx-61-1-1	2.8	3.0	132	166	3.0	2.2	89	77	1.5	11	0.15	8.60	66.55	4.35	19.42
CRSP NIEBE	2.8	2.3	147	165	2.3	3.0	13	12	2.0	9.1	0.26	9.20	62.77	1.26	14.65
Early Scarlet	2.8	2.8	155	177	3.3	2.8	15	6	4.0	9.6	0.19	9.10	62.62	3.62	16.32
Cameroon7-29	2.7	2.5	132	161	1.8	2.3	23	18	2.3	9.3	0.24	8.90	65.45	2.19	14.59
IT82E-18	2.7	2.7	121	162	3.3	2.0	73	50	4.3	11	0.20	9.10	49.55	9.66	15.95
IT98K-317-12	2.7	3.0	129	179	2.5	1.8	50	48	2.3	9.1	0.18	7.70	64.79	2.44	19.99
Vya	2.7	3.0	136	163	1.5	2.3	25	25	3.0	9.5	0.20	9.00	65.36	0.35	17.09
58-53	2.6	2.5	144	165	2.6	2.3	7.1	6.0	1.7	11	0.14	8.13	63.94	2.90	18.03
58-57	2.6	2.8	134	154	2.6	2.6	30	22	2.3	10	0.13	7.40	63.47	2.06	18.38
IT95K-181-9	2.5	2.7	144	186	2.9	2.5	89	76	1.4	10	0.17	8.75	45.11	12.08	19.50
Cam12-58	2.5	2.8	163	190	2.5	1.5	37	40	2.7	10	0.23	9.70	66.24	2.53	14.92
Iron Clay 101	2.5	2.3	131	153	1.9	1.4	21	21	4.7	12	0.13	7.05	54.46	6.63	17.59
Melakh	2.5	2.5	136	156	2.3	2.0	18	17	2.3	10	0.19	8.90	66.50	3.37	17.86
IT93K-93-10	2.4	2.5	135	163	2.4	2.2	42	39	4.7	11	0.19	8.75	37.10	15.11	8.41
Apagbaala	2.3	2.0	129	169	3.0	3.0	81	75	2.7	8.8	0.17	9.10	70.89	2.52	14.86
IT95M-190	2.3	2.3	139	168	3.8	3.0	20	15	1.5	8.2	0.24	10.10	64.49	4.12	17.30
UCR-830	2.3	2.3	149	164	2.3	1.5	9.2	5.8	4.7	13	0.15	7.10	44.74	7.75	11.86
CC-85-2	2.3	2.3	149	173	2.3	2.0	2.5	3.3	2.3	11	0.14	7.20	62.08	0.71	18.09
IAR7/8-5-4-1	2.3	2.2	140	153	2.6	2.8	5.5	4.8	3.2	9.7	0.17	8.30	65.61	2.72	16.15
IT83D-442	2.2	2.8	140	165	3.6	2.4	77	75	4.5	12	0.14	7.10	53.62	7.62	18.74
24/25B-9	2.2	2.0	173	187	3.3	3.5	78	45	1.8	14	0.14	7.20	61.09	2.75	18.75
IT95K-1479	2.1	2.1	139	158	2.0	1.8	25	28	2.5	9.8	0.21	8.10	61.81	2.91	16.43
24-125B-1	2.0	2.2	155	175	3.1	3.2	65	44	1.7	13	0.17	7.45	63.91	3.47	16.66
01CC-110-1	2.0	1.8	141	157	2.3	2.5	38	28	2.3	10	0.17	7.60	63.36	3.23	16.34
01CC-85	2.0	1.8	148	170	1.8	2.5	8.3	5.8	2.0	11	0.15	7.40	62.53	2.25	16.84
IT90K-284-2	2.0	2.4	152	174	2.4	1.2	40	34	4.4	11	0.23	9.80	51.45	10.14	19.85
IT93K-503-1	2.0	2.0	128	168	2.6	2.1	66	61	3.0	11	0.22	9.30	62.93	3.10	18.32
IT95K-1105-5	2.0	2.3	164	188	3.3	1.8	67	56	5.0	12	0.26	11.40	31.87	1.50	0.82
IT97K-819-132	2.0	2.8	146	167	2.4	2.2	20	18	4.8	11	0.23	9.60	55.39	9.66	19.73
IT98K-558-1	2.0	1.5	141	179	4.3	2.5	73	68	2.3	11	0.17	8.80	68.83	2.78	15.26
Mounge	2.0	2.5	156	172	1.8	1.5	6.5	6.5	4.0	10	0.18	9.60	51.58	2.48	10.92
Suvita 2	2.0	1.8	136	152	2.8	2.8	73	30	1.7	12	0.21	9.90	51.73	10.50	20.13
IT95K-1093-5	1.7	1.3	158	187	2.7	2.0	72	43	2.0	12	0.15	8.60	45.69	10.86	20.28
IT97K-556-6	1.7	2.3	141	173	2.7	1.7	43	29	4.7	11	0.25	11.10	46.41	11.10	18.80
UCR 779	1.7	1.8	146	160	1.9	1.9	10	2.6	4.5	12	0.18	7.90	47.46	9.20	13.44
Bambey 21	1.3	1.0	139	158	3.0	1.8	72	49	1.3	11	0.22	10.60	67.47	2.88	16.69
IT95K-1491	1.3	1.5	137	158	3.3	3.0	14	15	2.0	12	0.20	7.90	61.89	3.49	16.57
LSD	0.66	0.69	5.20	11.9	1.2	0.95	13	15	0.72	1.3					

[1] Values are ordered by Cook Doneness

[2] Raw physical characteristics were not measured in replicates

TABLE II
Correlations Between 13 Parameters Investigated

	Cook Done	Tactile Texture	Soak Abs(%)	Cook Abs(%)	Cook Broth Aroma	Cook Bean Aroma	Splt Testa(%)	Splt Cotyl(%)	Broth Opacity	Solid Loss(%)	Seed Wt(g)	L*
Tactile Texture	0.931[1]	…							…			
Soak Abs(%)	-0.330[2]	-0.289[2]	…									
Cook Abs(%)	0.592[1]	0.604[1]	…	…								
Ck Bean Aroma	…	…	…	…	0.439[1]							
Splt Testa(%)	0.403[1]	0.367[1]	…	0.587[1]	0.369[1]	…						
Splt Cotyl(%)	0.541[1]	0.526[1]	…	0.657[1]	0.289[2]	…	0.954[1]					
Broth Opacity	…	…	…	…	…	-0.364[1]	-0.294[2]	…				
Solid Loss(%)	-0.421[1]	-0.380[1]	0.551[1]	…	…	…	…		…			
Wt(g)/ seed	…	…	…	…	…	…	…	…	…	-0.470[1]		
Lnth(mm)/ sd	…	…	…	…	…	…	…	…	…	-0.415[1]	0.803[1]	
L*	…	…	…	…	…	0.351[1]	…	…	-0.460[1]	-0.451[1]	…	…
a*	…	…	…	…	…	-0.268[2]	.349[1]	.280[2]	…	.331[2]	…	-0.762[1]
b*	…	…	…	…	…	…	…	…	-0.480[1]	…	…	…

[1]Correlation is significant at the 0.01 level (2-tailed).

[2]Correlation is significant at the 0.05 level (2-tailed).

and broth opacity. Seed size did not have an effect on cooking time, contrary to the findings of Olapade et al (2002) and Demooy and Demooy (1990). “L” and “b” color space values were negatively correlated with opacity of the cooked broth, indicating that light colored raw cowpea seeds, produced cooked broth which was more translucent.

Tactile texture and cook doneness ratings were positively correlated, showing the ease in pressure put forth during chewing gives the impression of an adequately cooked sample. A seed with texture that is easily separated when chewed, however, is not always an indication that it is properly cooked. Twenty of the 56 varieties in Table I exhibited tactile texture ratings that were higher than doneness ratings. For example, variety IT97K-819-132 showed a tactile texture of 2.8, while cook doneness was only 2.0. It is necessary to measure the cook doneness parameter in addition to tactile texture. The two characteristics also correlated positively with cook absorption and negatively with soak absorption. The positive correlation was similar to the findings of Taiwo et al (1998) and Wang et al (2003), showing that higher absorption capacity (cook absorption) produced a softer bean. A high absorption capacity may enhance the gelatinization process, which is a major change that contributes to the softening of cowpea seeds. Although contrary to most legumes, Sefa-Dedeh et al (1978) found a negative correlation (-0.941, $P < 0.05$) between soak absorption and the cooked texture of cowpeas. He explained that seed coat thickness and hilum size affected water absorption during the initial stages of soaking, while protein content plays a major factor after 12 hr of soaking (Sefa-Dedeh and Stanley 1979). Thus, the amount of water absorption in cowpeas varies depending on different physico-chemical characteristics. Texture and doneness also correlated negatively with percent of soluble solids leached. Akinyele et al (1986) reported that legumes that were more cooked had increased leaching of total solids, contrary to the results of our study. Texture and doneness positively correlated with splitting of testa and cotyledons. When seeds are compressed, the initial resistance comes from the seed coat, and the continued resistance comes from the seed coat and cotyledon (Wang et al 2003). Splitting is an indication of the cotyledon softening; however, it is not always an indicator that the seed is done (Taiwo et al 1998). Taiwo et al (1997) found a similar correlation between texture measured by a penetrometer and seed splitting. After cooking, raw seeds that originated with predominantly torn seed coats or split cotyledons did not exhibit more splitting than raw intact seeds.

Aroma of cooked broth and bean were positively correlated, showing that cooked seeds with strong aromas produced aromatic broth. Broth aroma was positively correlated with splitting of the testa and cotyledon. Increased splitting may cause more leaching of volatile compounds, which contribute to broth aroma.

Splitting of the testa and cotyledon of cooked seeds were positively correlated, as expected. As seeds cooked, they eventually began to fall apart, usually starting with the tearing of the seed coat, followed by a separation or crack in the cotyledon (Taiwo 1997) (Figure 9 B and C). Certain samples, however, showed a cracked or split cotyledon while the coat was still intact. Demooy and Demooy (1990) reported that some cowpea varieties maintain a tough, intact seed coat even after the seed is thoroughly cooked. Splitting of the testa and cotyledon was positively correlated with cook water absorption, indicating that seeds with higher absorption capacity experienced more splitting. Results agreed with Taiwo et al (1998), who showed a 0.925 (P>0.01) correlation between cook absorption and splitting in cowpea seeds.

The percent of soluble solids lost after cooking correlated positively with the amount of water absorbed before cooking (soak absorption). Loss of solids did not, however, correlate with the total amount of water absorbed after cooking (cook absorption). Akinyele and Akinlosotu (1991) found that after soaking cowpea seeds for 4 h, there was a 41.9% increase in the seed sucrose content. This may explain the relationship between soak absorption and loss of solids in our study. Sucrose content influenced the loss of solids in three varieties. Varieties 24-125B-1 from Cameroon and KVx61-1-1 from Burkina Faso are considered “sweet” lines with approximately 6% sucrose. Their solid losses were high at 13.36 and 11.08, respectively. Mouride has about 2% sucrose and had a low loss of solids at 8.91. Unfortunately, sucrose levels were known for only the three varieties.

The sensory evaluations in some samples were variable, yet we were able to differentiate among the samples using a quick and inexpensive screening method that requires a small sample size. Although correlations were found, it is important to measure each cooking characteristic separately, as each reveals an attribute of legume quality. Soak absorption was not a good measure of how quickly seeds will cook, contrary to some studies. Raw physical characteristics also did not significantly correlate with most of the cooking characteristics and were not good indicators of cowpea cooking quality. Cowpeas must be evaluated by actual cooking trials, which is why the cooking method we developed is critically important.

Effect of location on cooking quality

Ten cultivars, grown in Fall Coachella Valley (FVC) and University of California Riverside (UCR) were evaluated to show the effects of variety, location, and variety by location interaction on cooking qualities (Tables III and IV). FCV climate was hot and dry, and UCR was moderate.

Variety and growing environment interaction affected cooked doneness, tactile texture, soak water absorption, bean aroma, cotyledon splitting, broth opacity, and soluble solid loss. Compared to the UCR location, four FCV varieties (58-53, Iron Clay 101, IT93-93-10, IT95K-1479) cooked significantly faster, as shown by higher doneness and tactile texture sensory values. The remaining six varieties were not significantly different for doneness and texture

TABLE III
Cooking Qualities of Ten Cowpea Varieties Cooked for 27 Minutes Differ When Grown in Two Locations

Variety	Location	Cook Done	Tactile Texture	Soak Abs (%)	Cook Abs (%)	Cook Broth Aroma	Cook Bean Aroma	Splt Testa (%)	Splt Cotyl (%)	Broth Opacity	Solid Loss (%)
IT85F-3139	FCV	4.3	3.8	127	186	2.5	2.3	100	98	1.0	8.6
IT85F-3139	UCR	4.0	4.3	139*	194	2.7	1.3	99	96	1.3	11*
IT89KD-288	FCV	3.0	2.7	133	163	1.5	2.0	24	22	2.8	8.0
IT89KD-288	UCR	2.7	2.7	131	159	1.8	2.3	40*	25	3.3	9.5*
CB46	FCV	2.8	3.0	137*	172	2.3	1.8	50	43	3.5*	7.7
CB46	UCR	3.0	3.3	130	186*	3.0	2.3	80	83*	2.3	8.4
58-53	FCV	3.0*	3.0*	146	168	2.3	2.0	11	10	1.5	11
58-53	UCR	2.3	2.0	141	161	3.0	2.6	3.3	2.0	1.8	12
IT95K-181-9	FCV	2.8	2.8	143	196*	3.2	2.2	99*	91*	1.2	9.7
IT95K-181-9	UCR	2.3	2.5	144	177	2.5	2.8	79	62	1.5	11
Iron Clay 101	FCV	3.0*	2.7*	137*	159	1.8	1.8	36*	35*	4.8	12
Iron Clay 101	UCR	2.0	2.0	125	148	2.0	1.0	6.7	6.7	4.6	12
IT93K-93-10	FCV	2.8*	3.0*	137*	162	2.4	2.4	40	40	4.8	11
IT93K-93-10	UCR	2.0	2.0	132	164	2.3	2.0	43	38	4.7	11
24-125B-1	FCV	2.3	2.3	166*	179	3.0	3.3	66	39	1.7	12
24-125B-1	UCR	1.8	2.0	145	171	3.3	3.0	65	49	1.8	13*
IT90K-284-2	FCV	2.0	2.5	153	170	2.5	1.0	26	23	4.5	10
IT90K-284-2	UCR	2.0	2.3	150	178	2.3	1.3	55*	46*	4.3	11
IT95K-1479	FCV	2.5*	2.8*	139	160	2.3	1.5	40*	40*	2.5	9.3
IT95K-1479	UCR	1.8	1.5	139	156	1.7	2.0	11	16	2.5	10
LSD of both locations		0.66	0.69	5.20	11.9	1.2	0.95	13	15	0.72	1.3

Locations: FCV = Fall Coachella Valley; UCR = University of California Riverside

*Value was significantly higher from that of the other location.

TABLE IV
Effects of Location, Variety, and Location-variety Interaction on Cooking Qualities

Source	Dependent Variable	Sig.
CULTIVAR * ENVIRONMENT	Doneness	0.001**
	Tactile Texture	0.036*
	Soak Absorption	0.021*
	Cook Absorption	0.172
	Broth Aroma	0.796
	Bean Aroma	0.028*
	Testa Splitting	0.098
	Cotyledon Splitting	0.034*
	Broth Opacity	<0.001**
	Solid Loss	0.017*
CULTIVAR	Doneness	<0.001**
	Tactile Texture	0.001**
	Soak Absorption	<0.001**
	Cook Absorption	<0.001**
	Broth Aroma	0.289
	Bean Aroma	0.009**
	Testa Splitting	<0.001**
	Cotyledon Splitting	<0.001**
	Broth Opacity	<0.001**
	Solid Loss	<0.001**
ENVIRONMENT	Doneness	0.036*
	Tactile Texture	0.022*
	Soak Absorption	0.637
	Cook Absorption	0.809
	Broth Aroma	0.329
	Bean Aroma	0.594
	Testa Splitting	0.212
	Cotyledon Splitting	0.140
	Broth Opacity	<0.001**
	Solid Loss	0.055

*significant ($P < 0.05$)

**highly significant ($P < 0.01$)

in the two locations. Four FCV varieties (CB46, Iron Clay 101, IT93-93-10, 24-125B-1) and one UCR variety (IT85F-3139) had a significantly higher soak water absorption, and the remaining five varieties were not significantly different. Three FCV varieties (IT95K-181-9, Iron Clay 101, IT95K-1479) and one UCR variety (CB46) had significantly higher cotyledon splitting, while the remaining six varieties were not affected by location. Broth opacity was significantly higher only in CB46 when grown in the FCV location. Soluble solid loss was significantly higher in IT85F-3139 and IT89KD-288 when grown in the UCR location. 24-125B-1, a high “sweet” variety (6% sucrose content), showed high loss of solids (13%) during the cooking trial, and even higher losses when grown at the UCR location. Results indicate that not all varieties reacted to location in the same way, but the overall effect of location was not significant.
Certain cooking qualities of the ten cowpea varieties were affected by a genetics-by-environment interaction.

The remaining three cooking qualities not affected by variety and location interaction were cook water absorption, broth aroma, and testa splitting. Cook water absorption and testa splitting were affected by varietal differences, but not by location. Broth aroma was not significantly affected by either variety or location, indicating similar scores among samples of the 10 varieties and at both locations.

Stage of seed maturity when harvested has been found to affect cooking quality of peas. Rowan and Turner (1957) reported that as peas mature, there is a possible increase in phytin content. Phytin plays the role of precipitating divalent cations and replacing them with monovalent cations. Divalent cations attribute to insolubility in the middle lamella pectin; thus, phytin helps allow the middle lamella pectin to become more soluble and the pea to soften during cooking (Mattson 1946, Mattson 1947). Chernick and Chernick (1963) reported that early maturing seeds that are harvested late produce the best cookability. Cookability was defined as peas that yielded the most puree, which depended on the softening of the seed. In our study, cowpeas that cooked faster, indicated by their texture and doneness, were grown in a hotter climate (FCV), which may have forced seeds to mature earlier and affect their cooking qualities.

Growing location has been reported to affect the cooking quality of legumes by changing their structure. Bhatty et al (1983) used Scanning Electron Microscopy to show that lentils, cooked for the same length of time, showed a complete loss of cellular structure when grown at one location, and a clearly visible and undercooked structure when grown at a different location. In a study by Iliadis (2003), long cooking lentil varieties significantly differed in their cooking times when grown in different soil types, while short cooking varieties did not significantly differ. He concluded that genotype affected cooking time variations more than environmental conditions. Iliadis (2003) also reported that varieties grown in different climates showed shorter cooking times in the climate that received higher rainfall.

Climate, soil type, moisture, and other factors interact with genetic factors to produce cowpeas of varying cooking quality. The efficient cooking procedure developed in these studies can assist scientists to more effectively evaluate cooking properties of cowpeas, as well as other legumes grown in different environments.

Effect of cooking times

At 27 min cooking time, overcooked (doneness = 5) cowpeas were cooked 5 min less, and undercooked (doneness = 1) cowpeas were cooked 5 min longer and compared to their 27 min cooked samples (Table V). The purpose of this experiment was to determine whether seeds that are over- or undercooked will produce accurate cooking qualities and should still be included in the screening method.

Cooking overcooked samples less brought doneness ratings to an adequately cooked range (3.0-3.3). Cooking undercooked samples longer, however, did not bring samples to an adequately cooked range; however, the increase in cooking time significantly affected the cooking qualities. As expected, manipulating cook time moved cooked doneness and tactile texture ratings to more adequately cooked values. The texture of seeds will soften with increasing cooking time (Taiwo et al 1997, Wang et al 2003).

Cooking overcooked seeds 5 min less did not have much impact on cooking attributes. Only IT84S2246 showed a significantly lower value in cook absorption and loss of soluble solids. Extended cooking times tend to cause a greater percentage of leached solids (Walker and Kochhar 1982, Wang et al

TABLE V

Cowpea Varieties Undercooked and Overcooked at 27 minutes were Cooked Again for Either Five Additional Minutes or Five Minutes Less

Variety	Location	Time (Min)	Cook Done	Tactile Texture	Soak Abs (%)	Cook Abs (%)	Cook Broth Aroma	Cook Bean Aroma	Splt Testa (%)	Splt Cotyl (%)	Broth Opacity	Solid Loss (%)
Overcooked Cowpeas Cooked 5 Minutes Less												
IT84S2246	05FCV-60	27	5.0*	5.0*	134	227*	1.8	1.8	98	98	1.7	11*
IT84S2246	05FCV-60	22	3.0	3.5	138	201	2.0	2.0	98	88	2.0	10
IT98K-128-2	05FCV-34	27	4.5*	4.5*	126	202	3.0	2.7	82	82	1.7	8.9
IT98K-128-2	05FCV-34	22	3.3	3.7	125	207	3.3	2.7	85	85	2.3	9.3
IT85F-3139	05FCV-68	27	4.3*	3.8	127	186	2.5	2.3	100	98	1.0	8.6
IT85F-3139	05FCV-68	22	3.0	3.5	123	178	3.0	2.5	100	90	1.5	8.5
Undercooked Cowpeas Cooked 5 Additional Minutes												
IT95K-1479	05-15-796	27	1.8	1.5	139	156	1.7	2.0	11	16	2.5	10
IT95K-1479	05-15-796	32	1.7	2.3*	136	165	3.7*	2.7	36*	38.7*	2.0	11
Bambey 21	05-15-813	27	1.3	1.0	139	158	3.0	1.8	72	49	1.3	11
Bambey 21	05-15-813	32	2.0*	2.0*	138	172*	2.7	2.7	86*	61	2.3*	11
IT95K-1491	05-15-799	27	1.3	1.5	137	158	3.3	3.0	14	15	2.0	12
IT95K-1491	05-15-799	32	2.0*	2.0	135	163	4.0	3.0	34*	73*	3.5*	12
UCR 779	01FCV	27	1.0	1.2	135	151	2.5	2.5	8	0	4.4	12
UCR 779	01FCV	32	1.0	1.5	136	150	3.0	2.5	17	2	5.0	12
LSD			0.66	0.69	5.20	11.88	1.16	0.95	13.32	15.33	0.72	1.29

*Value was significantly higher from that of the other location.

2003). Cooking undercooked cowpeas longer significantly increased cook absorption in varieties IT84S2246 and Bambey 21. Broth aroma significantly increased in variety IT95K-1491. Splitting and broth opacity significantly increased in varieties IT95K-1479, Bambey 21, and IT95K-1491. Taiwo et al (1997) and Taiwo et al (1998) reported that an increase in cooking time will increase the percentage of seed splitting, as well as cook absorption. The increase in broth opacity because cowpeas cooked longer begin to disintegrate and lose insoluble solids into the broth. Though the adjusted cooking time for undercooked cowpeas was not optimized, we were still able to find significant differences in their cooking qualities.

Cooked water absorption, splitting of testa and cotyledon, broth aroma, and opacity are qualities affected by cook time in undercooked samples. Thus, undercooked cowpeas should be cooked to an adequate doneness to determine their cooking attributes. Overcooked seeds, however, did not show a significant difference when cooked less and could remain overcooked during sensory evaluation of the cooking trial. Determination of the cooking time for the set of samples is very important and should be biased towards the overcooked side [and not undercooked]. While cooking undercooked samples to a doneness range of 1-2 showed a significant difference in cooking properties, samples should have been cooked until they reached an adequate level of doneness. Future studies should include optimum cook time for undercooked samples for a more accurate evaluation of their cooking properties.

CHAPTER IV

OBJECTIVE METHODS TO VERIFY PROPOSED SCREENING METHOD

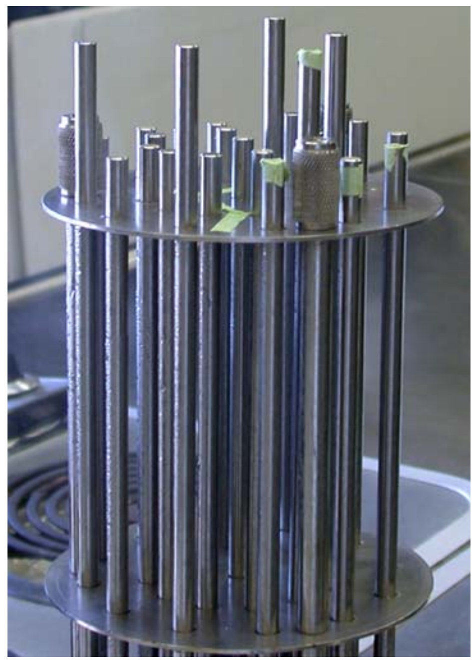
Materials and methods

Mattson bean cooker to verify cook doneness and tactile texture ratings

The Mattson bean cooker (MBC) used was made of a rack with 2 cm diameter apertures in the lowest plate of the rack (Figure 11). Each of twenty-five plungers weighed 90 g with flat faced tips 1.5 mm in diameter. For each test, 25 seeds soaked overnight, were placed in the apertures of the bean cooker. Cooking time commenced when the bean cooker was placed in a cooking container filled with enough deionized boiling water to submerge the seeds. Twelve of the 25 seeds were selected from one sample, and 13 seeds were selected from another sample. This setup was reversed and performed in a second test to obtain a cooking time for a 25 seed sample. Cooking time was recorded when 92% of the pins fell through the softened seeds (CT_{92}). Of the 70 samples, varieties IT85F-3139 (05FCV-68), IT97K-569-9 (05FCV-32), IT95K-1105-5 (05-15-805), IT97K-499-39 (05FCV), IT98K-128-2 (05FCV-34), IT98K-498-1 (05FCV-38), Mouride (05FCV-59), IT84S2246 (05FCV-60), and Bambey 21 (05-15-813) were no longer available and not included in this experiment.

The apparatus was used to establish the cooking times of the cowpea samples, which were then compared with doneness and tactile texture ratings by the trained evaluator. MBC times were used to confirm whether samples considered less cooked and harder in texture by the trained evaluator have longer cooking times, and samples considered more cooked and softer in texture have shorter MBC cooking times (i.e., verify if doneness and tactile texture ratings of less than 3 have longer cooking times).

A.



B.

Fig. 11. Mattson bean cooker **A.** Position of plungers at commencement of cooking, **B.** Plungers dropping during cooking

Texture Analyzer to verify cook doneness and tactile texture ratings

Texture of cooked samples were determined by compression in a test cell of the Ottawa Texture Measuring System (OTMS) using a Texture Analyzer (TA) (Model TA.HDi, Texture Technologies Corp., Scarsdale, NY/Stable Micro Systems, Godalming, Surrey, UK) (Figure 12). Ten cowpea varieties were selected, based on their cook doneness ratings assessed by the trained evaluator. Two varieties represented each rating on the 1-5 scale. Samples were not chosen based on tactile texture ratings because the main objective was to determine whether cook doneness ratings using mouthfeel correlated with TA results. Approximately thirty-five gram samples were soaked in distilled water for 16 hr and cooked until each sample reached its rating of cooked doneness. Samples were not cooked for the same cooking time (27 min) as the screening method because bags from the screening method contained only 5 g of seeds. Twelve gram cooked samples were placed in a 10 cm^2 compartment of the Ottawa cell and compressed through the ten wire extrusion grid at a speed of 1 mm/s. The objective was to determine whether the TA could verify mouthfeel evaluation by correlating with doneness ratings given by the trained evaluator. An additional objective was to verify the tactile texture method.

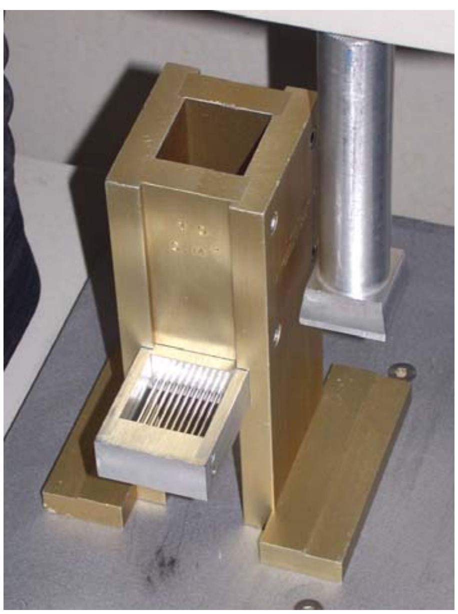


Fig. 12. Ottawa texture system

Dry oven method compared to a refractometer to determine soluble solid losses

A modified version of the AACC Method 44-15A (1999) was used to determine the percent of soluble solids lost from 19 cooked cowpea samples. Aluminum pans were dried overnight in an oven and allowed to cool to room temperature in an airtight desiccator before weighing. Broth of each cooked sample was swirled, and about 10 g was transferred to an aluminum pan. Pans were dried in a forced-air oven at 135°C for at least 16 hr. Pans were then removed with tongs and allowed to cool to room temperature in a desiccator. The pans with dried solids were weighed, and solid losses were calculated using the following formula:

$$\text{Soluble Solids} = \frac{((\text{dry solids in pan}) - (\text{dry pan}))}{((\text{pan + broth sample}) - (\text{dry pan}))} * 100$$

Of the 70 cowpea samples, 19 were selected for this experiment. These samples represented a broad range of solids lost using the °Brix refractometer method. Trials were performed in triplicates. The objective of this experiment was to compare results of the modified AACC method and the °Brix refractometer method in determining solid loss.

Statistical analysis

Means were correlated using Pearson's Correlation in SPSS. Each trial was performed in duplicates unless otherwise stated.

Results and discussion

Mattson bean cooker

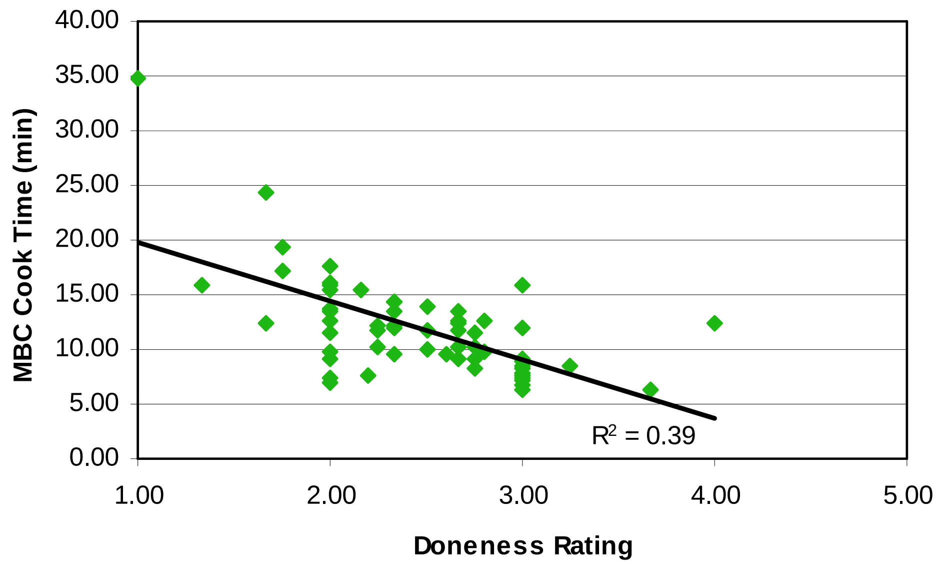
The time required for 92% of the plungers to penetrate the testa and cotyledon of the seed was used in this experiment (Proctor and Watts 1987). Table VI shows cooking time measured by the MBC compared with doneness and tactile texture ratings by the trained evaluator. Cook doneness and tactile texture significantly correlated ($P < 0.01$) with the MBC at -0.63 and -0.65, respectively (Figure 13). Proctor and Watts (1987) reported that the percentage of cooked beans established by a sensory panel corresponded with the percentage of cooked beans obtained by the MBC. Wang et al (2003) reported that cooking time of field peas established by the tactile method was the time at which 80% of peas were cooked using the MBC. Sensory methods relate to the MBC and can be used as a measure of cooking time. Due to a short supply of samples for this experiment, sensory ratings were largely in the 2-3 range, creating less variability. A wider range may have produced a higher correlation.

A disadvantage of the MBC is that it only measures how easily the plungers break through the seeds; however, parenchyma cells may still be in clumps, creating a gritty and uncooked feeling when consumed. Grittiness can be detected by the tactile method, but even more so by the doneness method, giving the sensory methods an advantage. Another disadvantage of the MBC method was that it required time to setup in between each sample trial, in addition to the time required for each sample to complete cooking. The

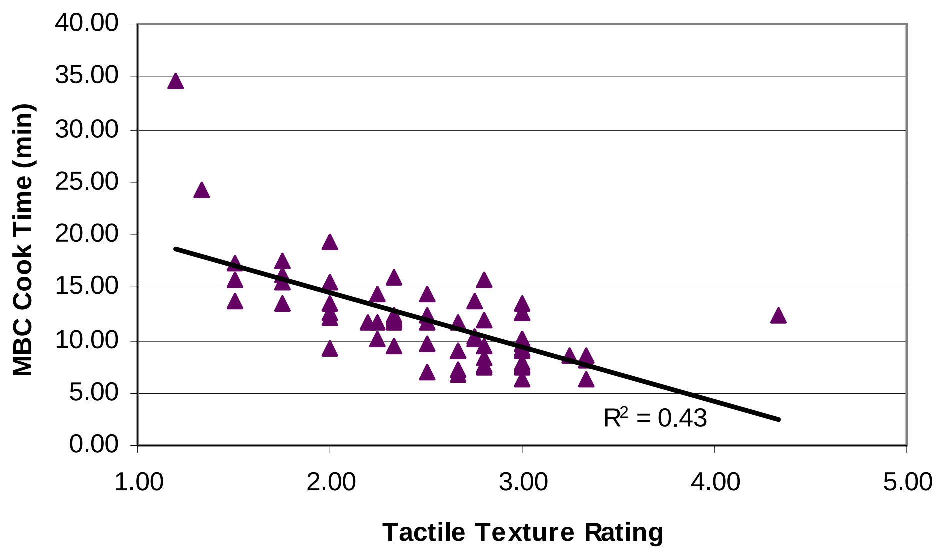
TABLE VI
Cooking Time Measured by Mattson Bean Cooker Compared with Doneness and Tactile Texture Ratings by the Trained Evaluator

Variety	Location	CT92[1] (min)	Doneness[2]	Tactile Texture[3]
Prima	05FCV-3	6.31	3.00	3.00
CB27	05FCV	6.33	3.67	3.33
IT89KD-288	05FCV-58	6.77	3.00	2.67
IT90K-284-2	05FCV-61	6.93	2.00	2.50
Iron Clay 101	05FCV-57	7.10	3.00	2.67
IT97K-819-132	05FCV-13	7.45	2.00	2.80
1393-2-3 (-)	05FCV-71	7.47	3.00	3.00
IT83D-442	05FCV-53	7.63	2.20	2.80
1393-1-2-2 (+)	05FCV-70	7.71	3.00	3.00
IT98K-428-4	05FCV-36	7.82	3.00	3.00
IT86F-2014-1	05FCV-65	8.17	3.00	3.33
IT95K-181-9	05FCV-25	8.35	2.75	2.80
CB46	05-15-820	8.48	3.00	3.33
IT93K-693-2	05FCV-19	8.50	3.25	3.25
58-53	05FCV-49	8.95	3.00	3.00
IT82E-18=UCR 232=Big Buff	04 Shafter	9.03	2.67	2.67
IT93K-2046	05FCV-63	9.04	3.00	2.67
Iron Clay 101	05-11-	9.15	2.00	2.00
CB46	05FCV-40	9.16	2.75	3.00
UCR-830	05FCV-69	9.48	2.33	2.33
58-57	05FCV-48	9.51	2.60	2.80
Mounge	05FCV-51	9.72	2.00	2.50
IT93K-93-10	05FCV-67	9.75	2.80	3.00
Cam12-58	05FCV-45	10.11	2.50	2.75
CB46	05 Tulare	10.18	2.67	3.00
CC-85-2	05FCV-55	10.21	2.25	2.25
IT98K-317-12	05FCV-33	10.22	2.67	3.00
Early Scarlet	05FCV-4	10.32	2.75	2.75
CRSP NIEBE	05FCV-46	11.58	2.75	2.25
IT90K-284-2	05-15-834	11.58	2.00	2.33
IT89KD-288	05-15-845	11.69	2.67	2.67
Melakh	05FCV-50	11.70	2.50	2.50
IAR7/8-5-4-1	05FCV-42	11.78	2.25	2.20
IT98K-205-8	05FCV-37	11.85	3.00	2.80
24-125B-1	05FCV-16	12.00	2.33	2.33
UCR 779	05FCV-18	12.10	2.33	2.33
58-53	05-15-809	12.15	2.25	2.00
IT85F-3139	05-15-833	12.30	4.00	4.33
IT97K-556-6	05-15-825	12.35	1.67	2.33
Cameroon 7-29	05FCV-44	12.37	2.67	2.50
IT93K-93-10	05-15-831	12.55	2.00	2.00
KVx-61-1-1	05FCV-8	12.65	2.80	3.00
Vya	05FCV-56	12.65	2.67	3.00
CB27	05 Kearney	13.53	2.67	3.00
Apagbaala	05-15-827	13.57	2.33	2.00
IT93K-503-1	05-15-816	13.57	2.00	1.75
IT98K-558-1	05-15-800	13.67	2.00	1.50
IT95K-1479	05FCV-23	13.82	2.50	2.75
IT95M-190	05-15-832	14.30	2.33	2.25
IT95K-181-9	05-15-797	14.35	2.33	2.50
24/25B-9	05FCV-17	15.40	2.17	2.00
01CC-85	05-15-01CC-85-2	15.43	2.00	1.75
IT95K-1491	05-15-799	15.82	1.33	1.50
IT95K-207-21	05-15-804	15.83	3.00	2.80
IT93K-503-1	05-11-451	15.94	2.00	2.33
Suvita 2	05FCV-11	16.17	2.00	1.75
IT95K-1479	05-15-796	17.21	1.75	1.50
01CC-110-1	05-15-CC110	17.52	2.00	1.75
24-125B-1	05-11-449	19.24	1.75	2.00
IT95K-1093-5	05-15-798	24.27	1.67	1.33
UCR 779	01FCV	34.69	1.00	1.20

[1] Time required for 92% of plungers to fall
[2] Rating based on 1-5 scale (1 = undercooked, 5 = overcooked)
[3] Rating based on 1-5 scale (1 = difficult or unable to smash, cotyledon is hard, 5 = easily pressed into a mush)



A.



B.

Fig. 13. A. Correlation between the MBC and doneness rating, **B.** Correlation between the MBC and tactile texture rating

estimated time for one sample was 32 min using the MBC. Although it provides valuable and objective information, the time and labor required make it difficult to evaluate numerous samples. Doneness and tactile texture sensory methods are easier and allow for cooking and evaluation of 25 samples in only 1 hr. The sensory methods considerably reduce the amount of energy used for cooking.

Our results verified that subjective ratings could differentiate the varieties the same way as the MBC by distinguishing seeds that required less cooking time. The sensory methods could provide the legume industry and plant breeders with a faster, more cost efficient method for evaluating the cooking time of legumes.

Texture Analyzer

Texture Analyzer (TA) results for the cooked cowpea samples were in the range of 655.85 N -1110.24 N force g^{-1} (Table VII). Adequately cooked samples had an extrusion force of 655.85 N with a doneness of 3 when cooked for 27 min in the screening method. Sefa-Dedeh et al (1978) reported a similar force when measuring cowpea texture cooked for 27 min using the Ottawa Texture Measuring System test cell, with an eight-bar wire extrusion grid.

TA results significantly correlated with doneness and tactile texture ratings at -0.67 and -0.69, respectively ($P < 0.05$) (Figure 14). Scanlon et al (1998) also found a significant correlation between the TA and a trained panel, which used mouthfeel to measure cooking time of lentils.

In our results, the extrusion forces were significantly different for cooked

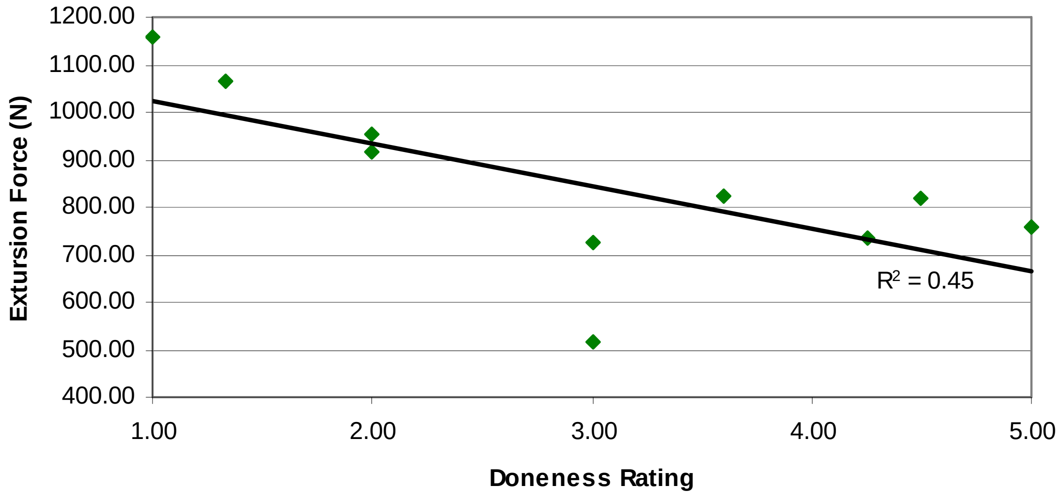
TABLE VII
Doneness of Cooked Seeds Measured by the Texture Analyzer and Trained Evaluator

Variety	Location	TA Force(N)	Cook Done[1]	Tactile Texture[2]
UCR 779	01FCV	1157	1.00	1.20
Bambey 21	05-15-813	1063	1.33	1.00
Iron Clay 101	05-11-	955	2.00	2.00
Suvita 2	05FCV-11	914	2.00	1.75
CB46	05-15-820	517	3.00	3.33
IT93K-2046	05FCV-63	725	3.00	2.67
IT85F-3139	05FCV-68	734	4.25	3.75
IT98K-498-1	05FCV-38	824	3.60	3.20
IT98K-128-2	05FCV-34	820	4.50	4.50
IT84S2246	05FCV-60	760	5.00	5.00
LSD		114	0.66	0.69

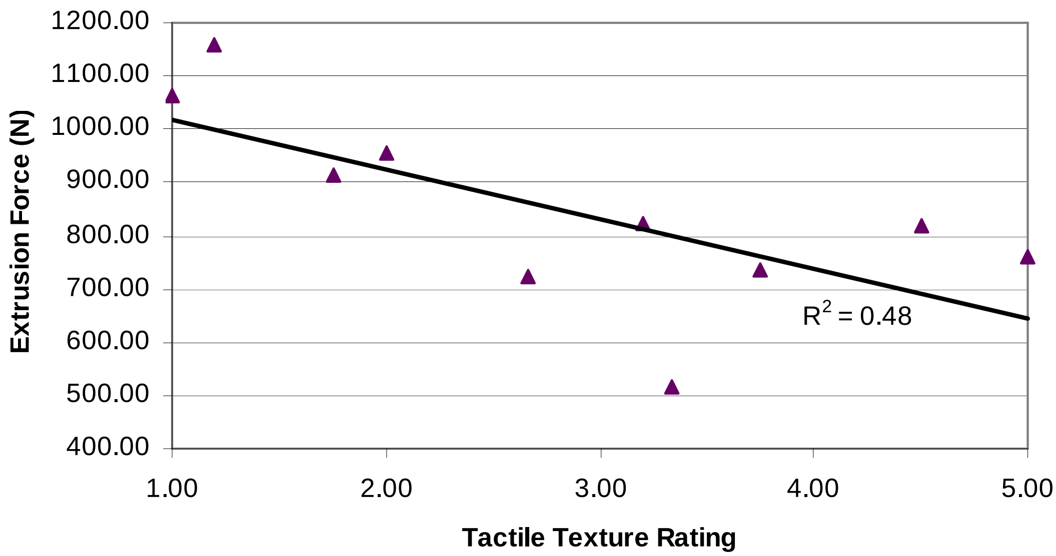
[1] Sensory rating based on 1-5 scale (1 = undercooked, 5 = overcooked)

[2] Sensory rating based on 1-5 scale (1 = difficult or unable to smash, cotyledon is hard, 5 = easily pressed into a mush)

Sensory rated seeds were cooked for 27 min



A.



B.

Fig. 14. **A.** Correlation between Texture Analyzer and doneness rating, **B.** Correlation between Texture Analyzer and tactile texture rating

ratings 1, 2, 3, and 4 showing the softening of the cotyledon during cooking. Because a rating of 3 is considered adequately cooked, the TA showed that it is able to measure past the degree of doneness. Extrusion force did not differ significantly for doneness ratings 4 and 5. Doneness measured by the trained evaluator significantly differed for all ratings. Mean scores indicated that the Texture Analyzer could not distinguish seeds once they were overcooked, but the trained evaluator was able to by using mouthfeel. Overcooked seeds are over hydrated, losing most of their firm structure, and are as undesirable as undercooked seeds. Mouthfeel can measure textural parameters that objective methods cannot and also measure a specified parameter with greater sensitivity than an instrument (Bourne 1982).

The disadvantages with the TA are similar to that of the MBC apparatus. Although the TA provides objective results and is able to measure the softening of the seed during cooking, it cannot detect grittiness, which is a key characteristic of doneness. The TA is also expensive, requires larger sample size, and may not be available in all laboratories. The doneness and tactile texture sensory methods are inexpensive, quick and can be used in place of the TA method to measure cooking time of legumes.

Dry Oven Method

Soluble solids lost from cooked cowpea seeds ranged from 7.66-13.36% by the °Brix refractometer method and 7.47-11.53% by the modified AACC Oven Method 44-15A (Table VIII). The refractometer readings were significantly higher

Table VIII
Solid Losses Measured by Brix Refractometer Method and AACC Method 44-15A

Variety	Location	Refractometer Method	AACC Method
CB46	05FCV-40	7.66	7.47
IT89KD-288	05FCV-58	7.97	7.51
CB46	05-15-820	8.42	9.05
CB27	05FCV	8.68	7.88
1393-2-3 (-)	05FCV-71	8.96	6.79
CB46	05 Tulare	9.23	7.32
CB27	05 Kearney	9.46	7.66
01CC-110-1	05-15-CC110	9.96	8.76
Melakh	05FCV-50	10.21	7.25
IT82E-18=UCR 232=Big Buff	04 Shafter	10.75	8.40
CC-85-2	05FCV-55	11.01	8.76
01CC-85	05-15-01CC-85-2	11.13	9.30
IT86F-2014-1	05FCV-65	11.50	9.99
24-125B-1	05FCV-16	11.92	11.00
IT83D-442	05FCV-53	12.15	10.05
UCR 779	01FCV	12.17	10.06
Iron Clay 101	05FCV-57	12.24	9.33
UCR-830	05FCV-69	12.77	10.70
24-125B-1	05-11-449	13.36	11.53
Mean for each method		10.50	8.88

for all samples, except variety CB46, source 05-15-820. Higher values were attributed to the procedure to measure remaining broth weight. The modified AACC method acquired remaining broth weight by weighing on a scale. The refractometer method calculated broth weight using a formula, which did not take into account evaporation and may have resulted in a higher weight. Further studies should include weighing the remaining broth to investigate whether solid losses are closer to values produced by the AACC method.

The two methods were significantly correlated (r=0.84, $P < 0.01$), indicating the refractometer method measures loss of soluble solids from legumes (Figure 15). Akinyele and Akinlosotu (1991) reported that after 4 hr of soaking there was a 32.2% decrease in oligosaccharides (verbascose, stachyose, raffinose) causing flatulence in cowpeas. In other legumes, Han and Baik (2006) showed that after 12 hr of soaking, the oligosaccharides decreased 22.9 - 50.1%, 74.6 %, and 56.3% in lentils, chickpeas, and soybeans

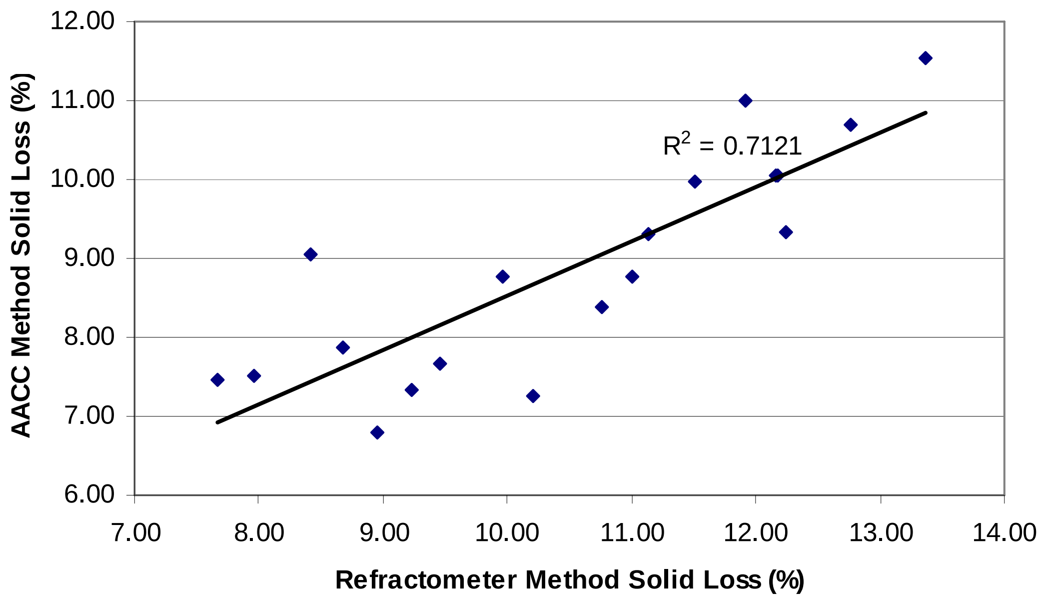


Fig. 15. Correlation between the refractometer method and the AACC method

respectively. After cooking, however, lentils were the only legumes to decrease further in their oligosaccharide content, while chickpeas and soybeans increased by cooking after soaking. The increase was explained by the possible release of bound oligosaccharides during cooking. Nutrients, such as calcium, iron, and thiamin are also lost during soaking (Akinyele and Akinlosotu 1991). Future research is needed to determine the composition of solids leached from the cooked cowpeas to determine whether these are nutrients or antinutrients.

The °Brix refractometer method can measure 25 cooked samples in approximately 20 min. This is a significant reduction in time compared to weighing and drying samples overnight in a forced air oven. This method also consists of few experimental steps, which might decrease human error. There is no established method that uses a °Brix handheld refractometer to measure solids for legumes. Bakr and Gawish (1992) used an Abbe' refractometer to measure soluble solids loss in cowpeas. Their value did not take into account the final weight of the broth and the initial seed weight, as shown in the formula used in our experiment:

$$\text{Soluble Solids} = \frac{(°\text{Brix})\ (\text{Final Broth WT (g)})}{\text{Initial Seed WT (g)}} * 100$$

Our results showed that soluble solid losses of cowpeas measured by the Brix refractomter method could be used with as much certainty as the modified AACC Method 44-15A. The advantage in time saved is tremendous.

CHAPTER V

CONCLUSIONS

It is important to produce legume varieties with qualities that meet desired consumer preferences; thus, an effective and low-cost method to analyze cooking quality attributes was developed. The correlations among the characteristics were studied. Raw seed size was not related to cooked sensory properties, notably cooking time. Raw seeds of lighter color produced more translucent cooked broth. Doneness and tactile texture positively correlated with cook absorption and seed splitting. Aromatic beans produced more intense broth aroma and had higher seed splitting. Although relationships were found between the cooking characteristics, it was important to measure each characteristic separately and as cooked seeds.

The rapid screening method presents an easy approach to cook many varieties and determine several of their cooking qualities through sensory evaluation. The method also allows scientists to evaluate legumes grown in different locations or cooked for different times.

The screening method measures cook doneness and tactile texture using sensory evaluation. A TA and MBC significantly correlated with doneness and tactile texture results, verifying the sensory methods as a means to measure cook time of legumes. A new procedure was developed as part of the rapid screening method for measuring soluble solid loss from cooked legumes. The method significantly correlated with the AACC oven Method 44-15A (0.844, $P < 0.01$). A considerable amount of time could be saved by using the rapid screening method compared to commonly used methods. The screening method is low in cost, quick, and repeatable, allowing breeders to differentiate legume cooking properties between cultivars and environment. Legumes can then be ranked into preferred and less preferred categories due to specific cooking requirements of the food processor or consumer.

Use of the rapid screening method in a breeding program

The method described in our research has significant potential for legume breeding and improvement programs. It is simple, inexpensive, and requires small samples of grain of early generation lines that are cross bred with lines of disease and insect resistance to improve their cooking quality. The method can be applied to breeding nurseries where reference varieties with acceptable food quality are included as standard samples. The standard reference samples can be used in cooking trials to compare with experimental samples. Experimental samples that are adequately cooked can be advanced to the next breeding stage. Undercooked samples can be eliminated immediately or cooked longer and re-evaluated if they have other outstanding characteristics. Selections can be made for cooking quality in earlier generations based on the simple evaluations used in the screening method.

Legume samples of only 5 g can be placed in plastic bags, soaked overnight, and cooked for a standard time. A trained evaluator can use scales established from the standards to rate samples for texture, mouthfeel, aroma, seed splitting, and broth appearance. For determination of cooking dry matter losses the refractometer could be used. The process to evaluate 25 samples requires an estimated time of 2 hr on the first day and 5 hr on the second day (Figures 16 and 17). Larger quantities of sample can be used by increasing the size of the bags and the cooking container. The screening method involves allowing time for the evaluator to gain experience and become familiar with the methodology.

The screening method applied in early generations could eliminate poor quality lines in the breeding program and expedite the process of developing new varieties with acceptable cooking properties. The equipment used in the method is easily accessible, inexpensive, and can be used in most places. It can be a great tool for breeders to rapidly screen hundreds of legume/cowpea lines based on cooking quality.

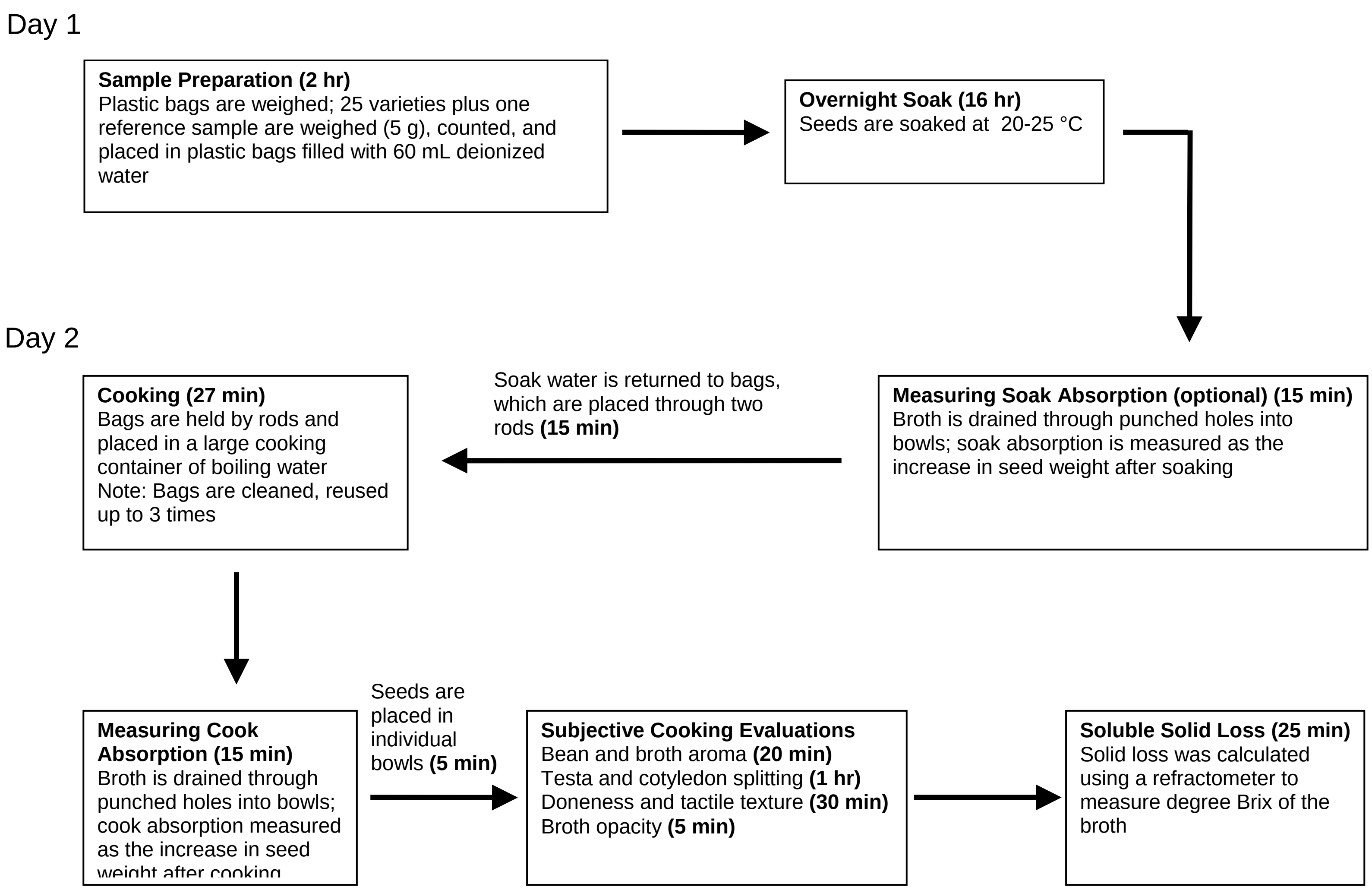


Fig. 16. Flow chart of rapid screening method and estimated time requirements to evaluate 25 samples

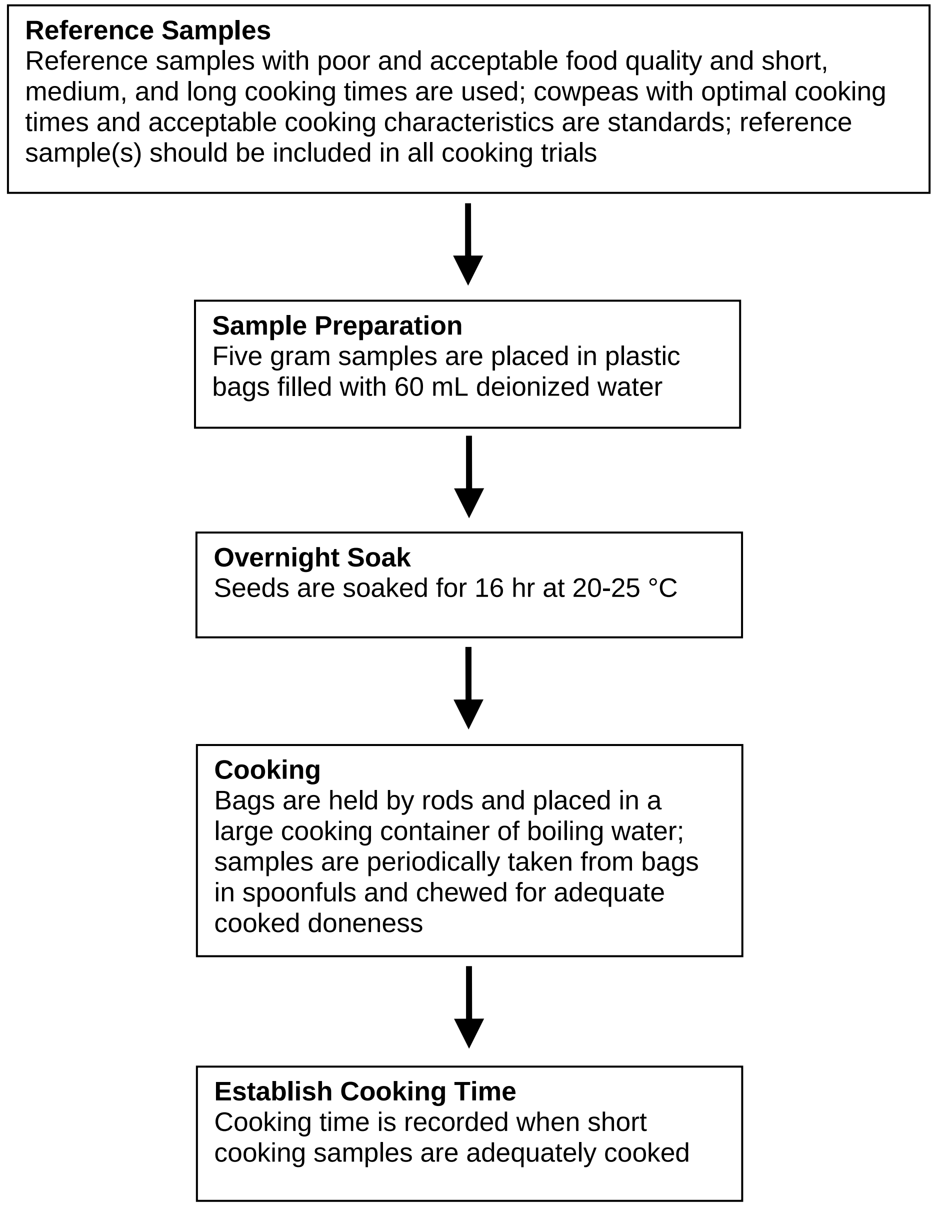


Fig. 17. Flow chart of procedures to establish cooking time of reference samples

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